



US007733106B2

(12) **United States Patent**  
**Dozier, II et al.**

(10) **Patent No.:** **US 7,733,106 B2**  
(45) **Date of Patent:** **Jun. 8, 2010**

(54) **APPARATUS AND METHOD OF TESTING SINGULATED DIES**

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(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 94 days.

(21) Appl. No.: **11/532,494**

(22) Filed: **Sep. 15, 2006**

(65) **Prior Publication Data**

US 2007/0063721 A1 Mar. 22, 2007

**Related U.S. Application Data**

(60) Provisional application No. 60/718,820, filed on Sep. 19, 2005.

(51) **Int. Cl.**  
**G01R 31/02** (2006.01)

(52) **U.S. Cl.** ..... **324/755; 324/754; 324/158.1; 438/113**

(58) **Field of Classification Search** ..... **324/754-765, 324/158.1**  
See application file for complete search history.

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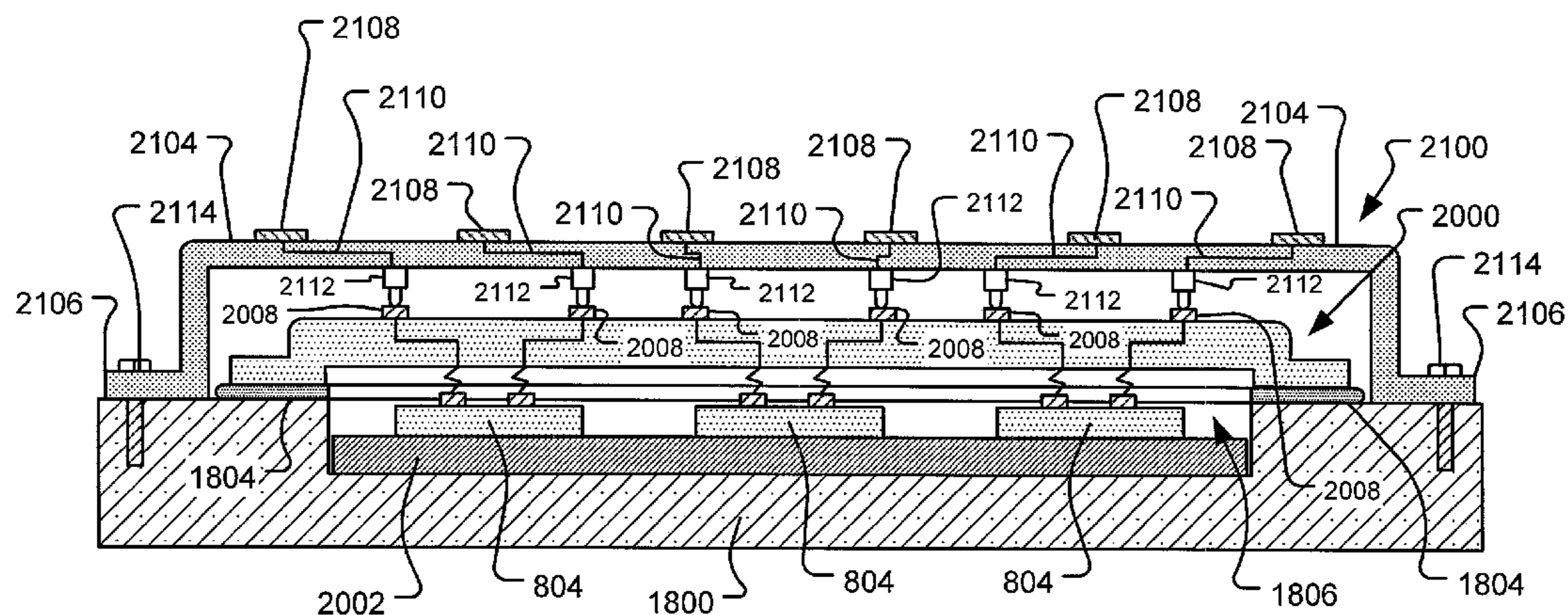
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(57) **ABSTRACT**

An exemplary die carrier is disclosed. In some embodiments, the die carrier can hold a plurality of singulated dies while the dies are tested. The dies can be arranged on the carrier in a pattern that facilitates testing the dies. The carrier can be configured to allow interchangeable interfaces to different testers to be attached to and detached from the carrier. The carrier can also be configured as a shipping container for the dies.

**30 Claims, 22 Drawing Sheets**



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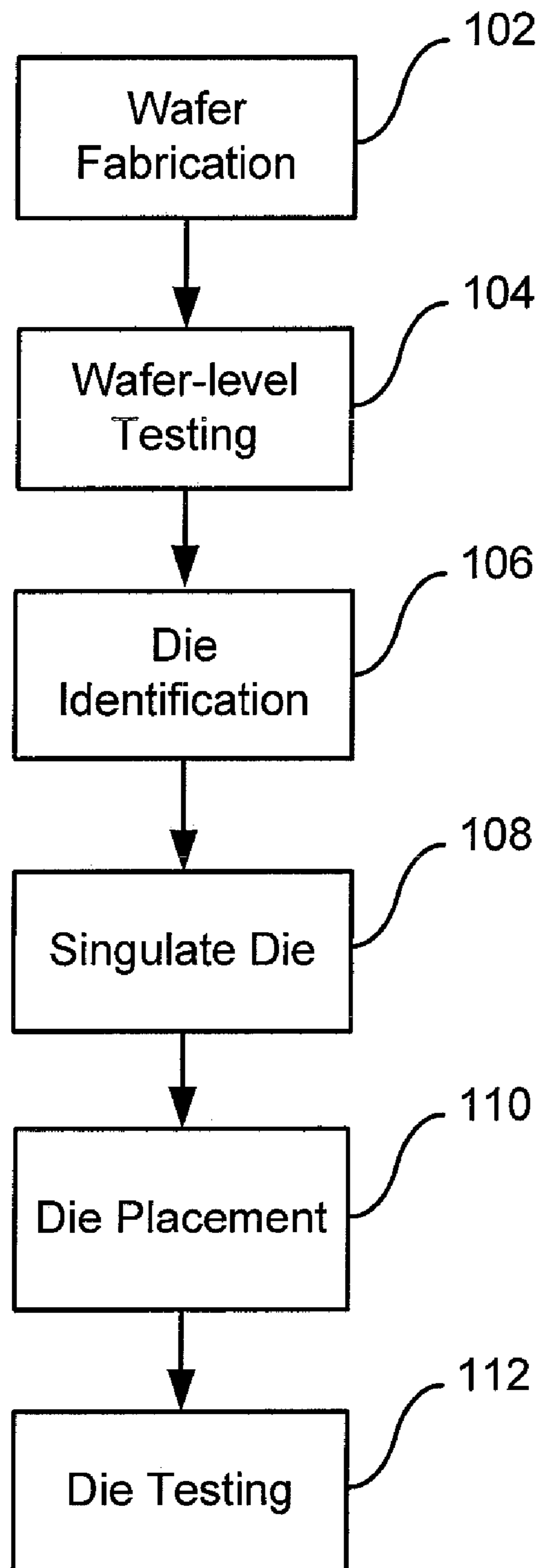


Fig. 1

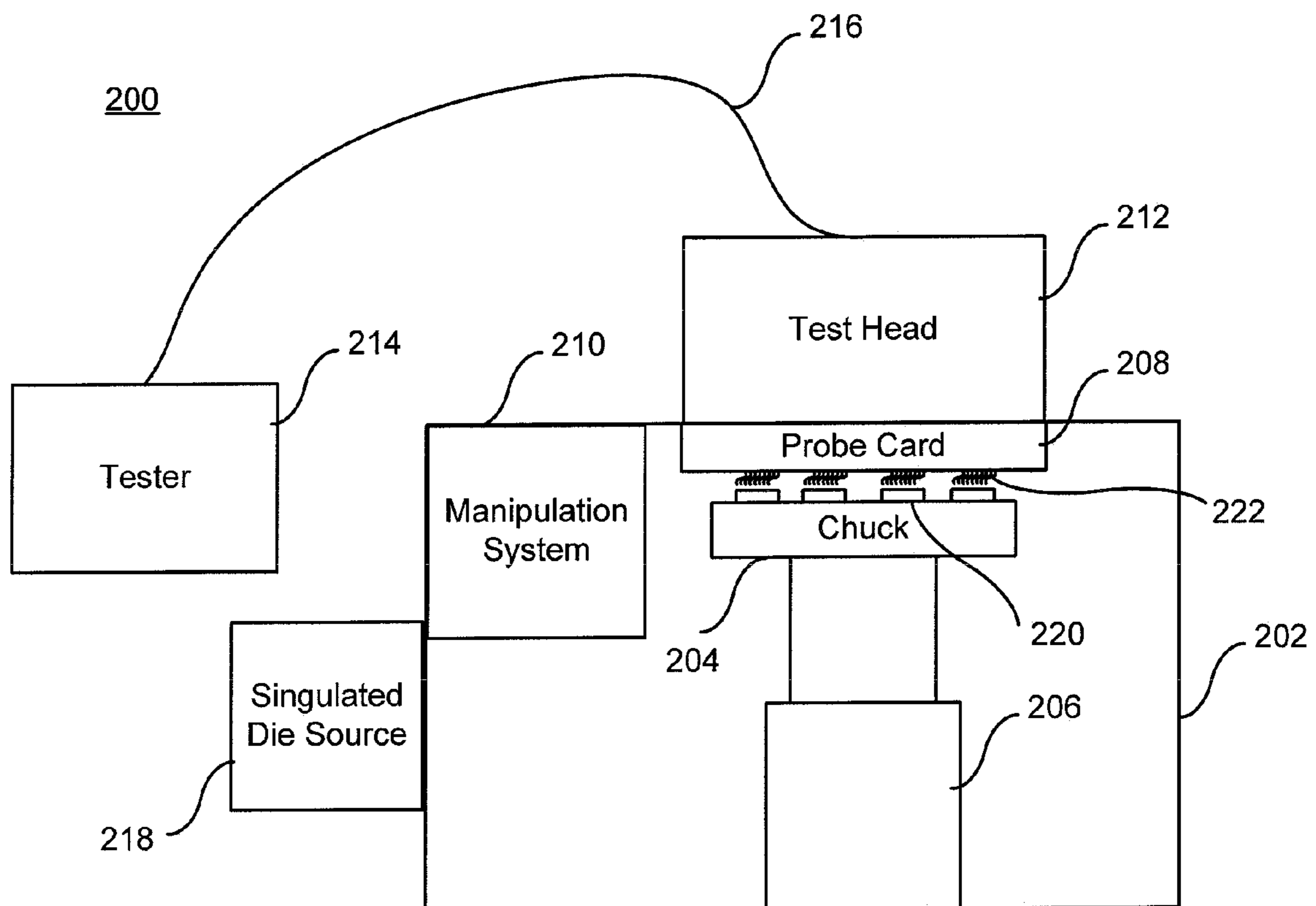


Fig. 2

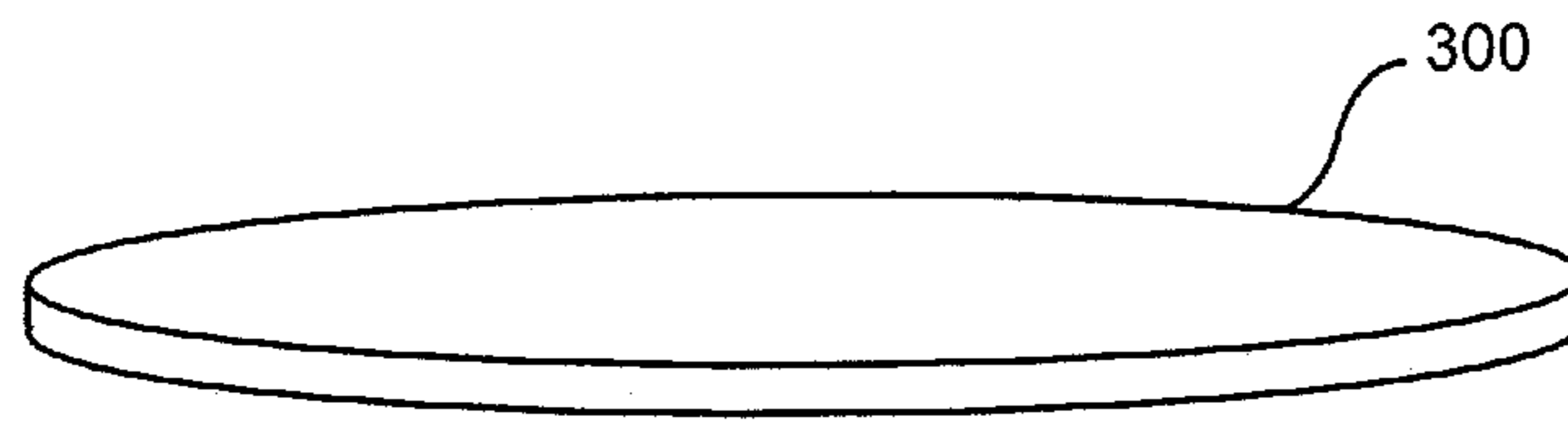


Fig. 3

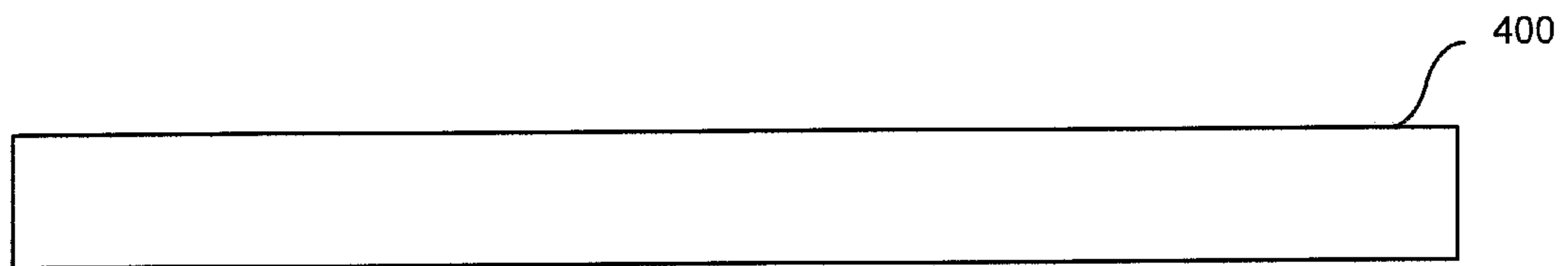


Fig. 4a

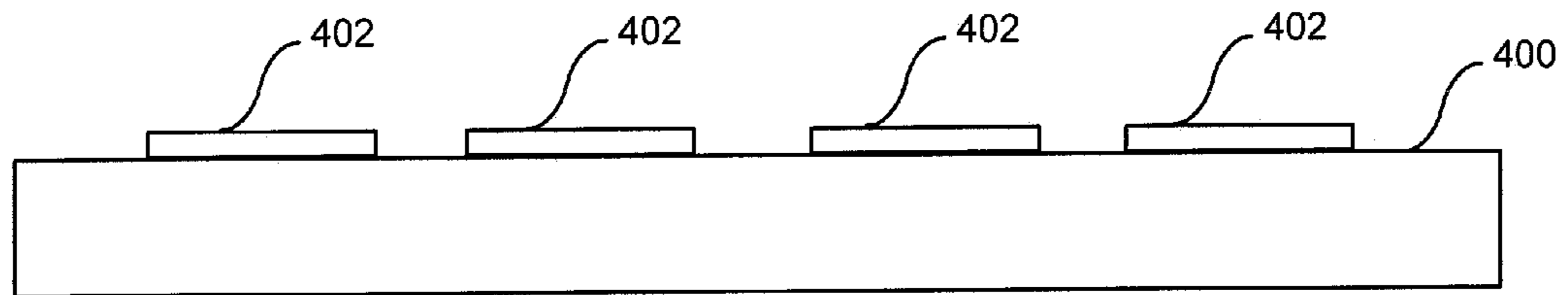


Fig. 4b

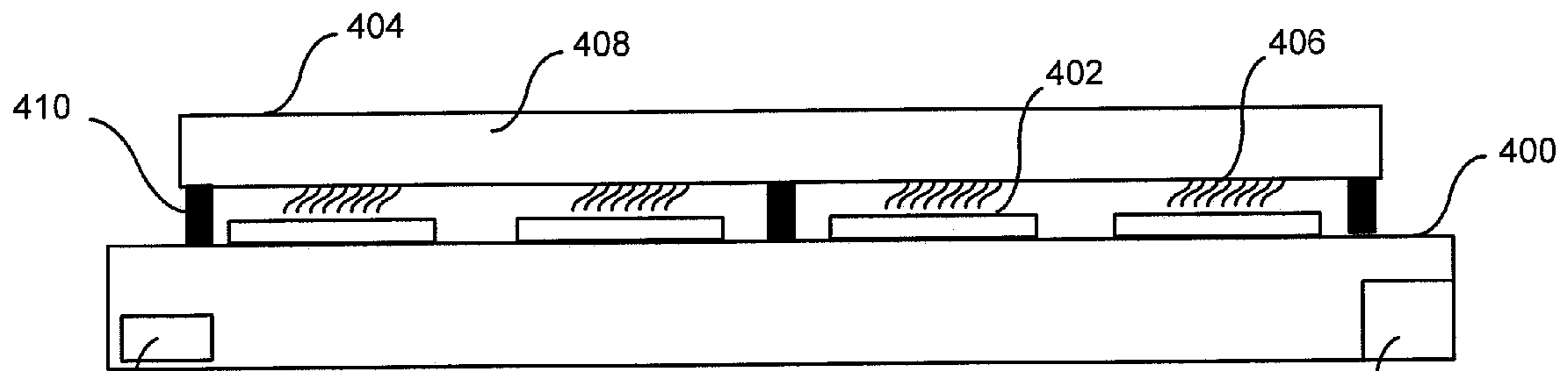


Fig. 4c

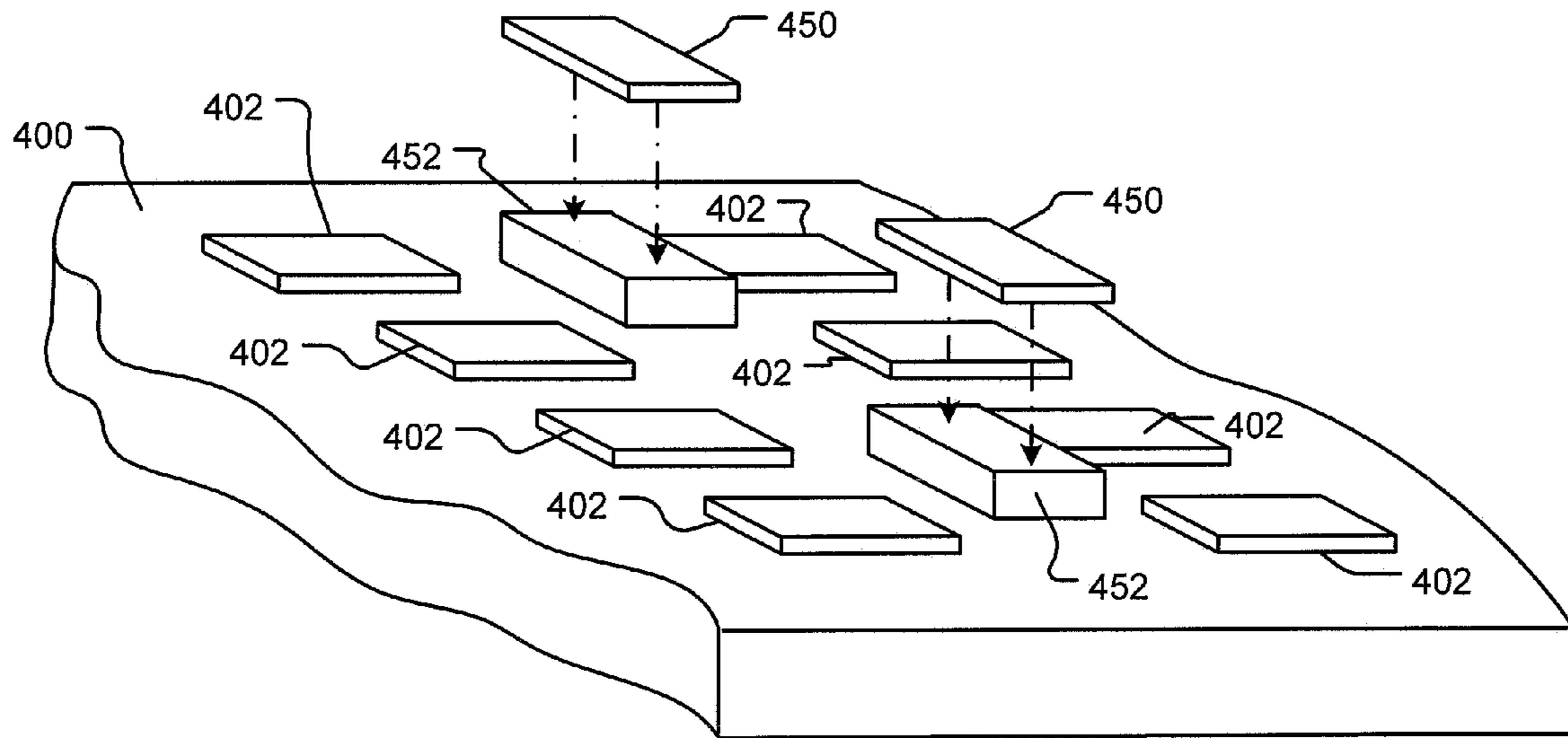


Fig. 4d

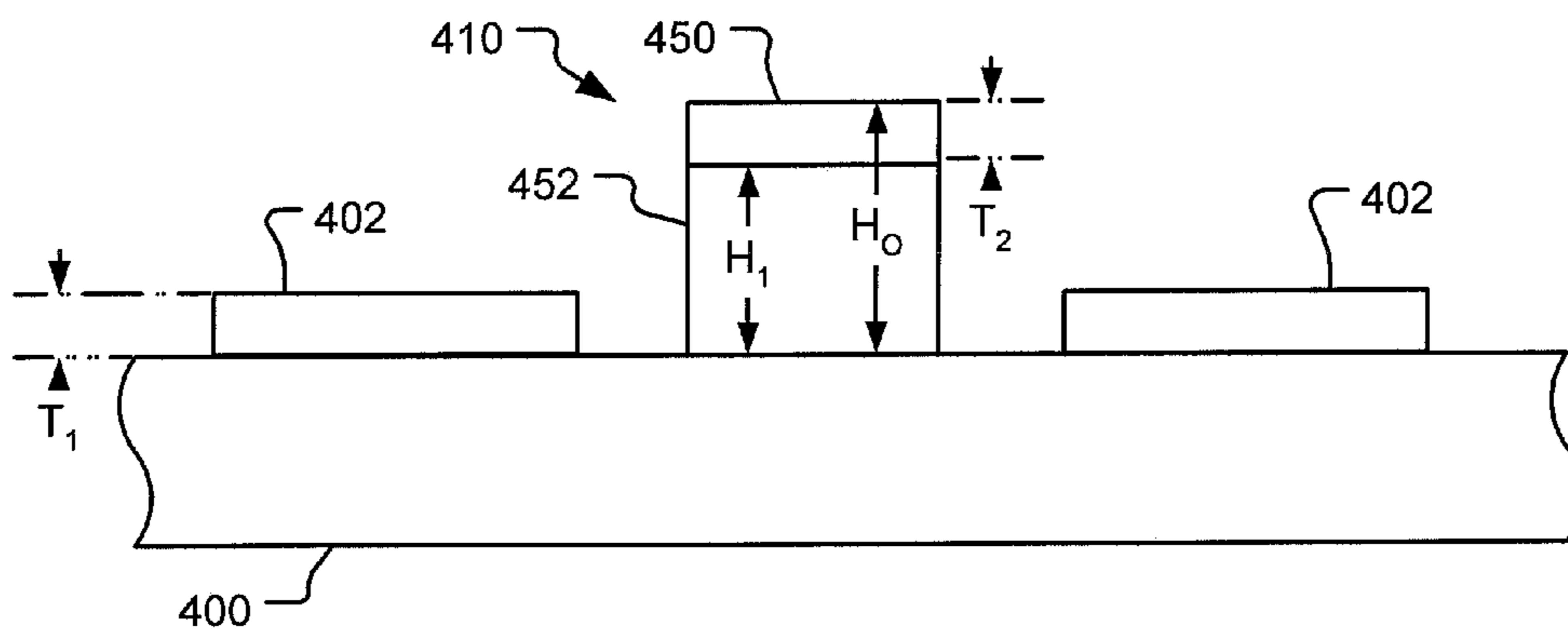


Fig. 4e

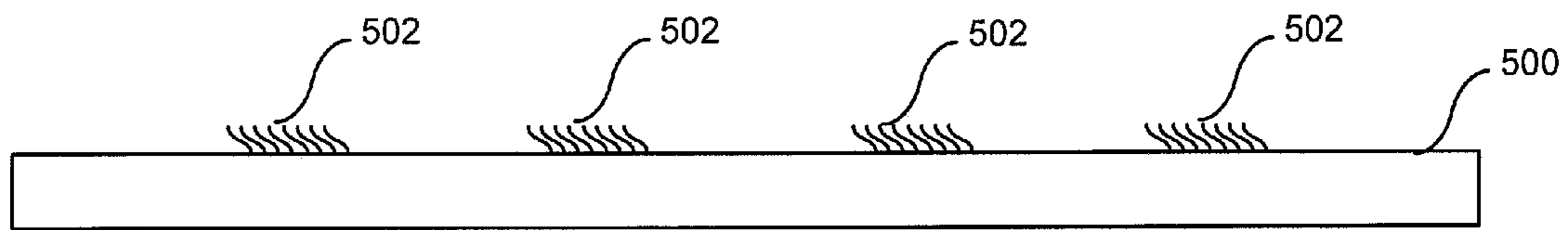


Fig. 5a

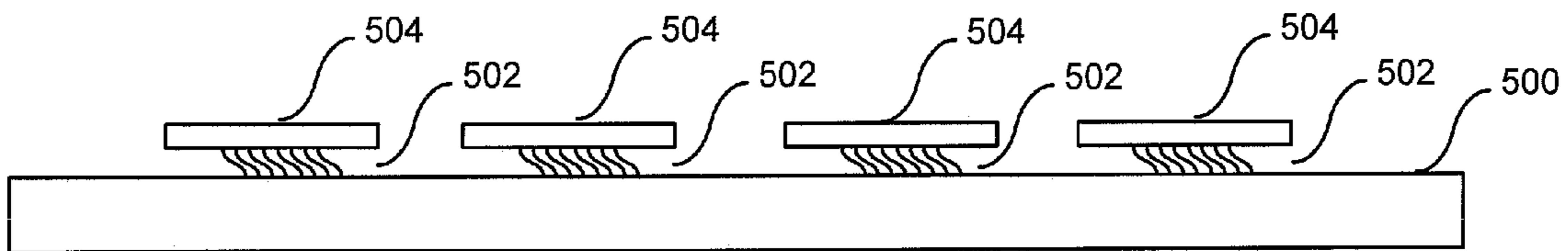


Fig. 5b

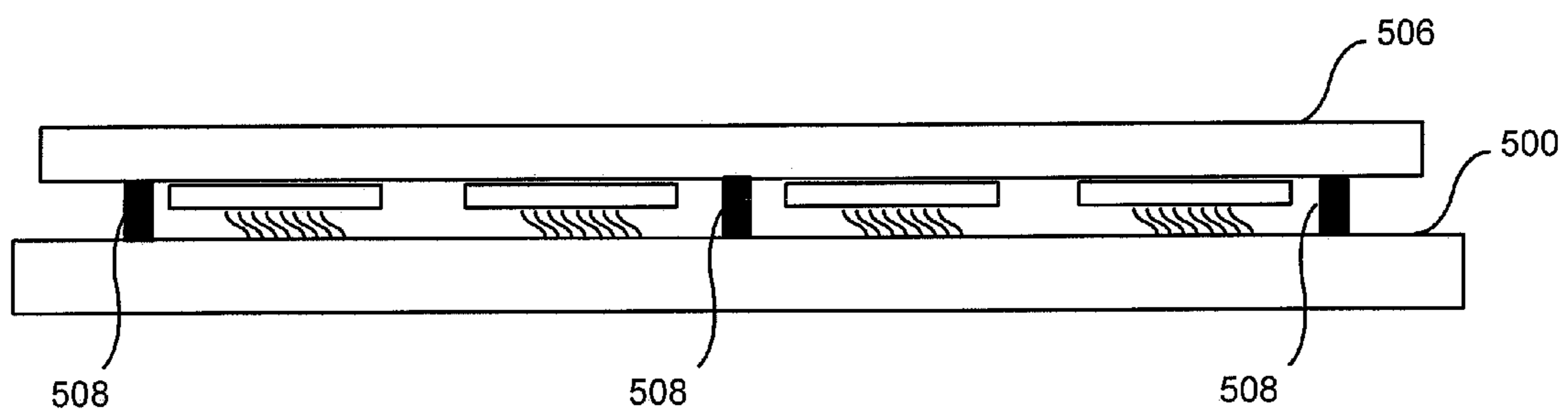


Fig. 5c

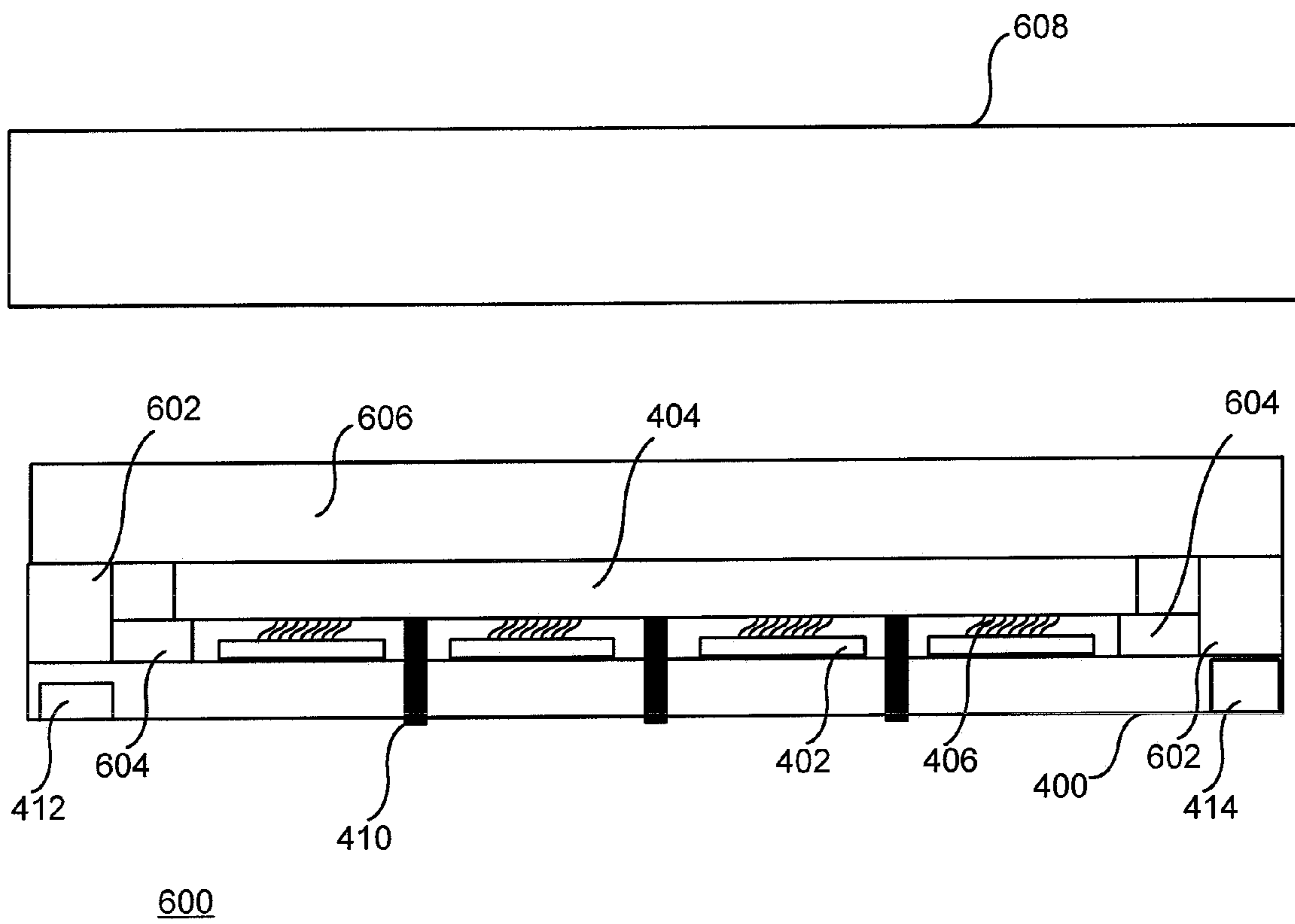


Fig. 6



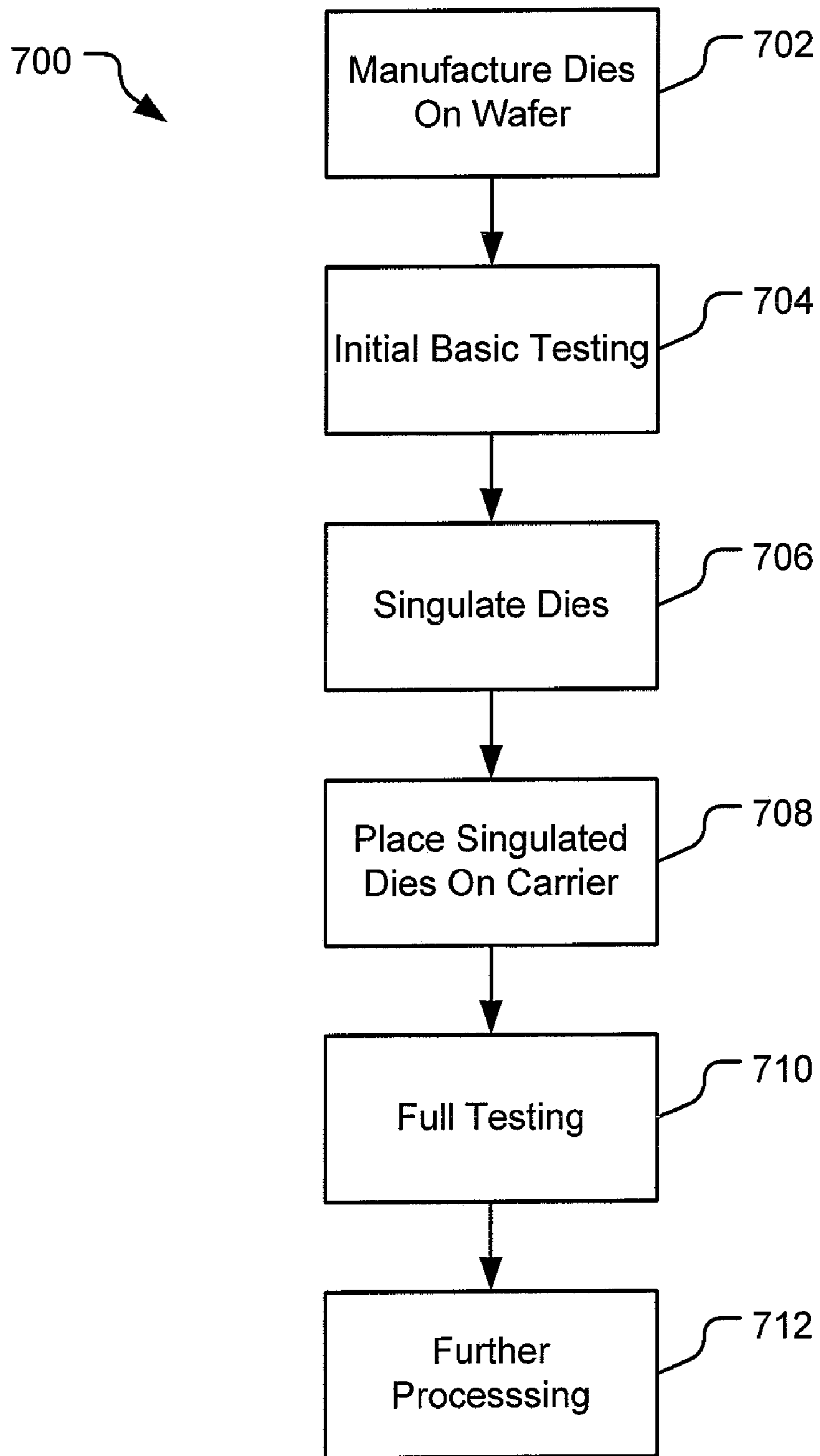


Fig. 7

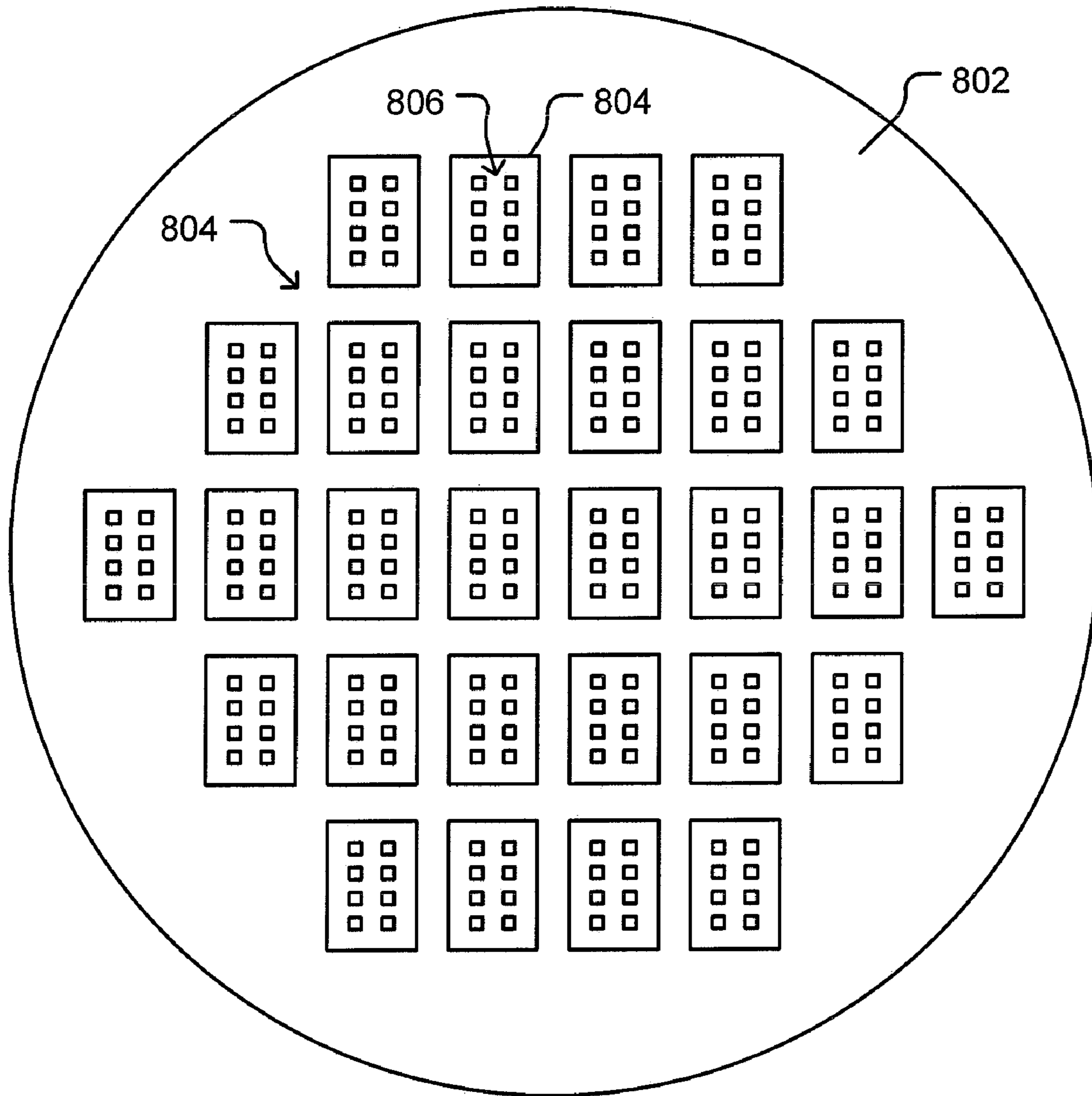


Fig. 8

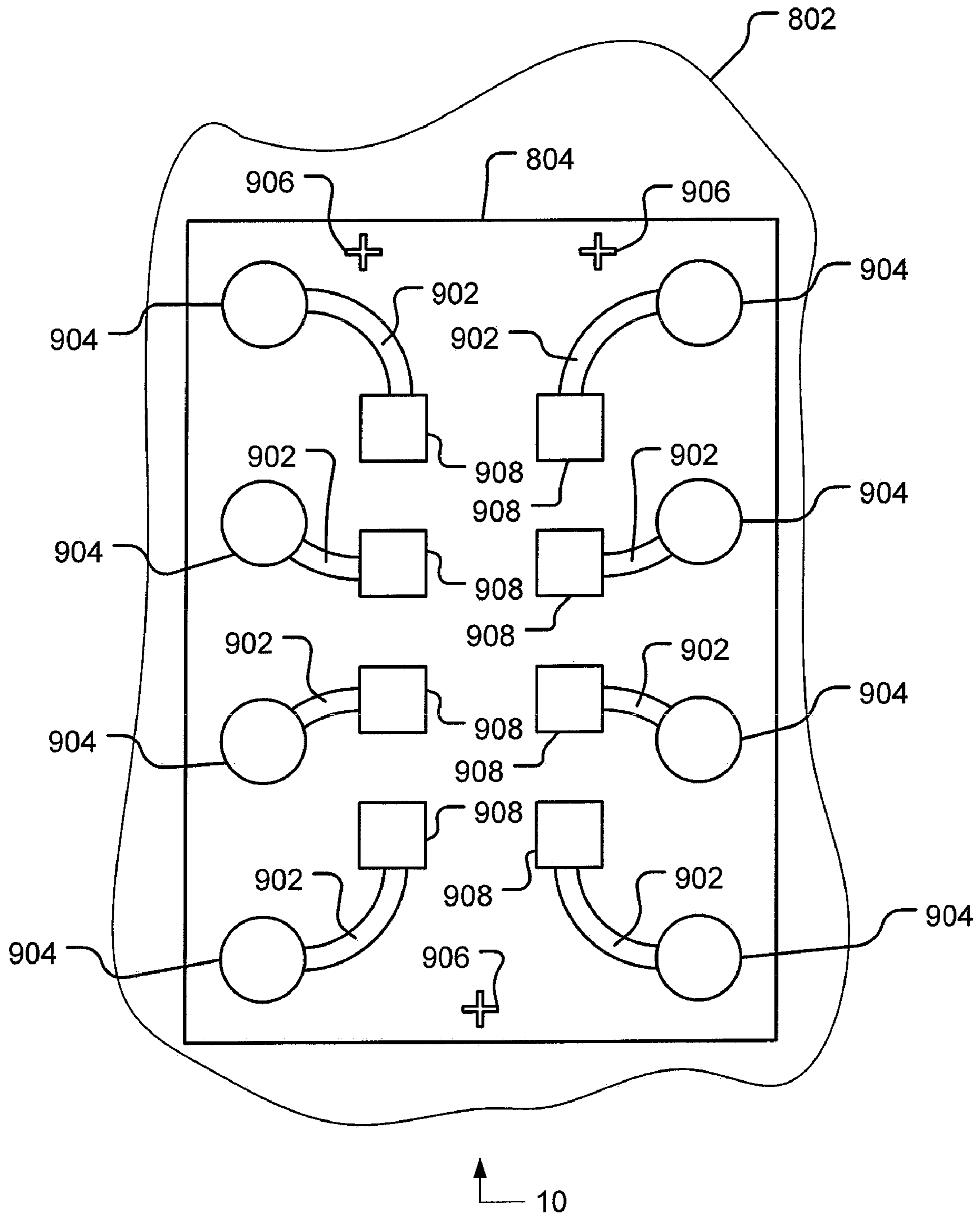


Fig. 9

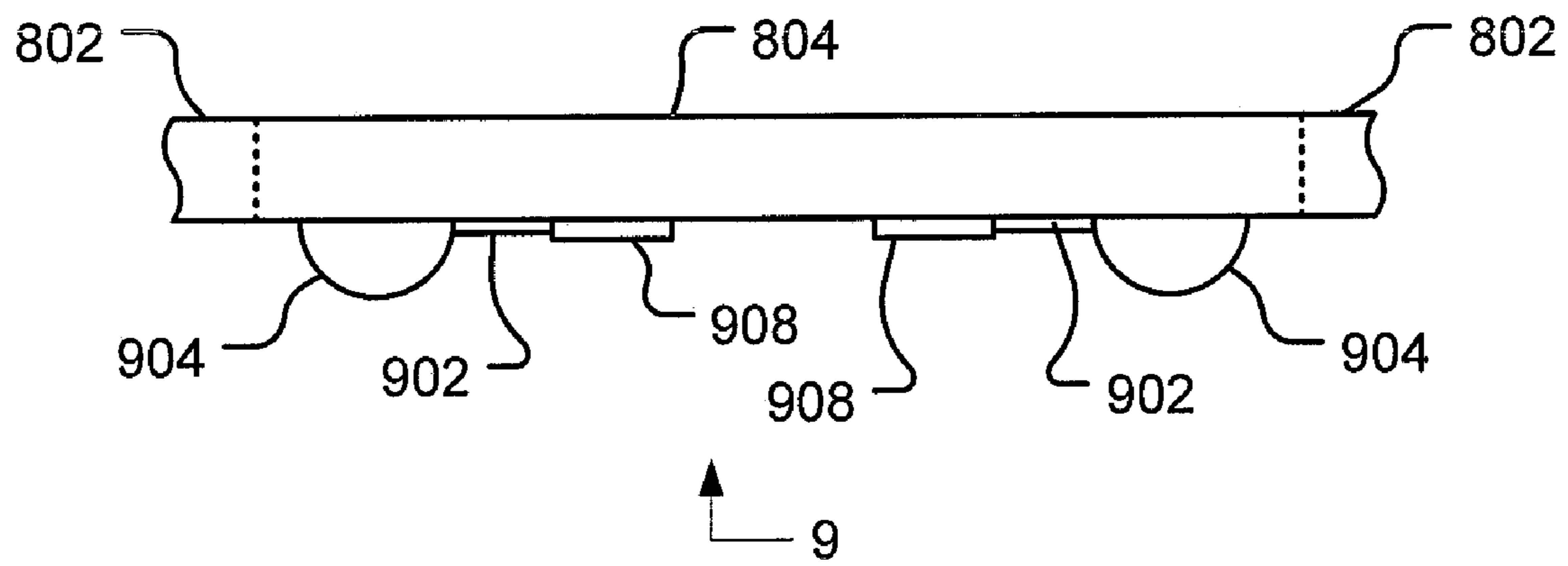


Fig. 10

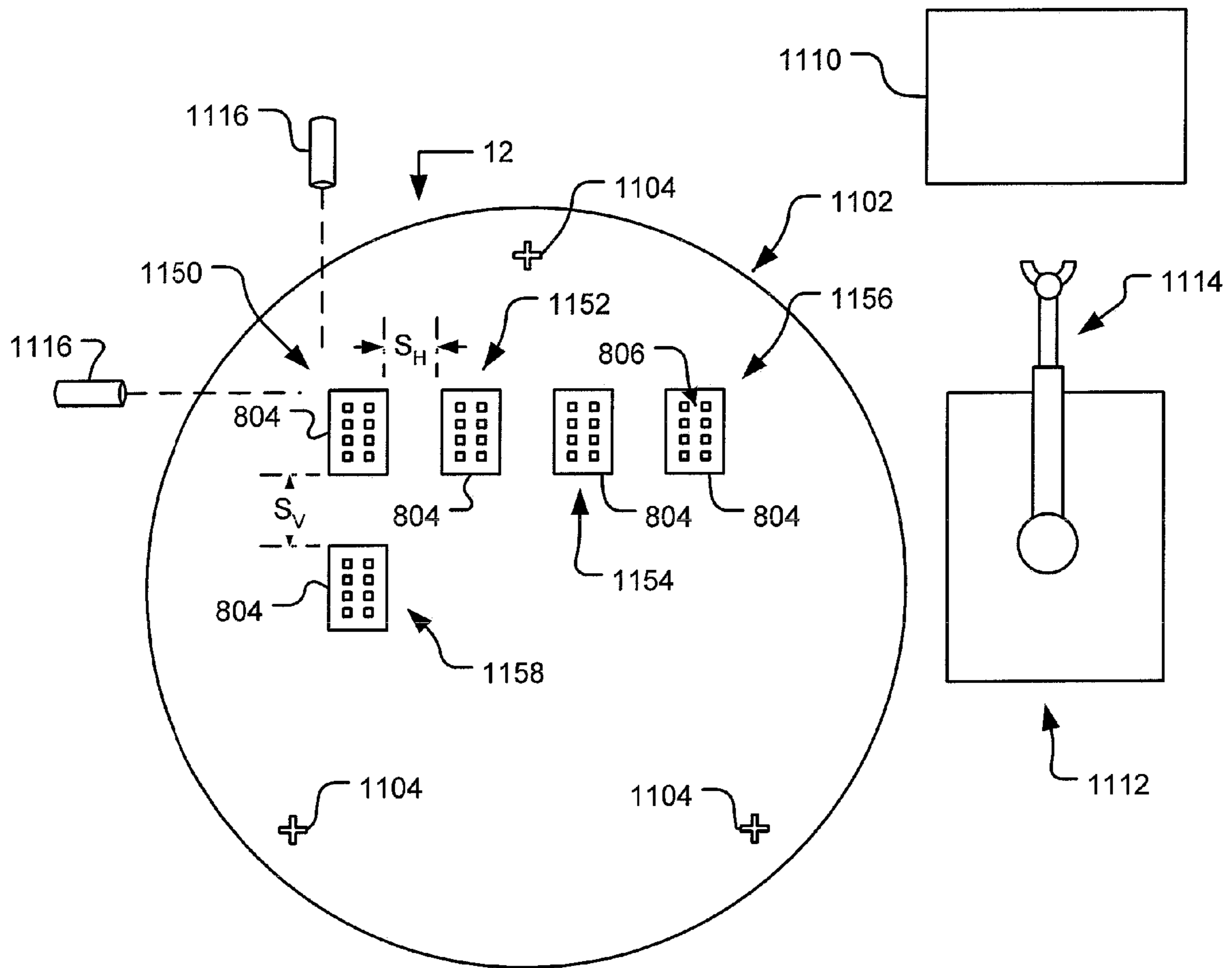


Fig. 11

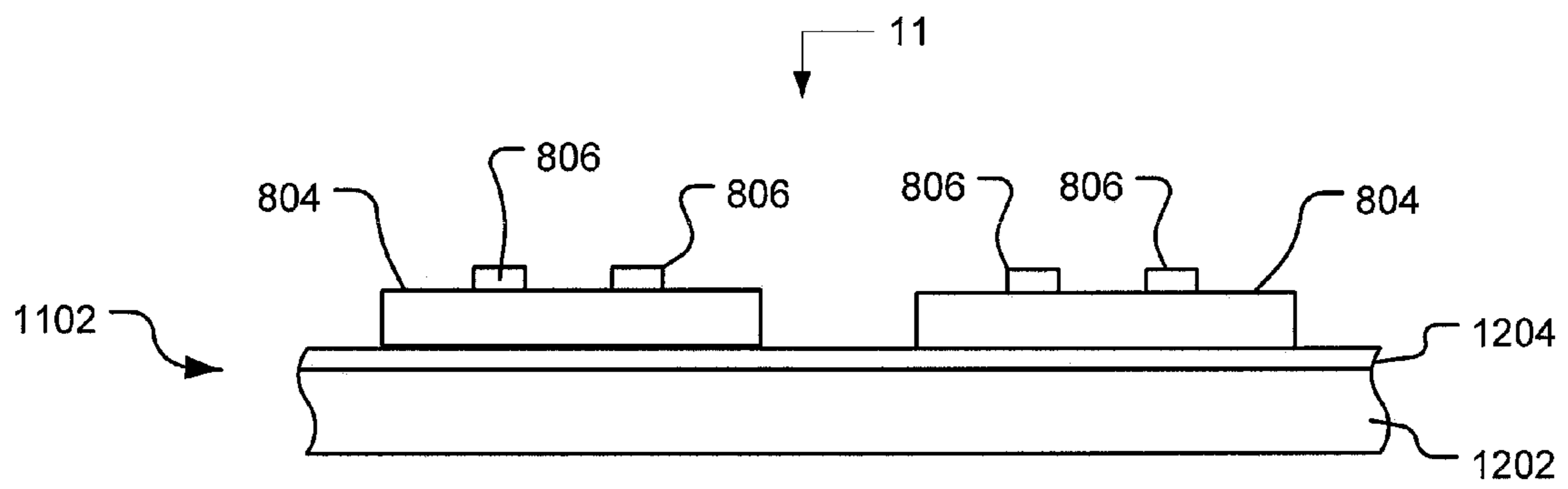


Fig.12

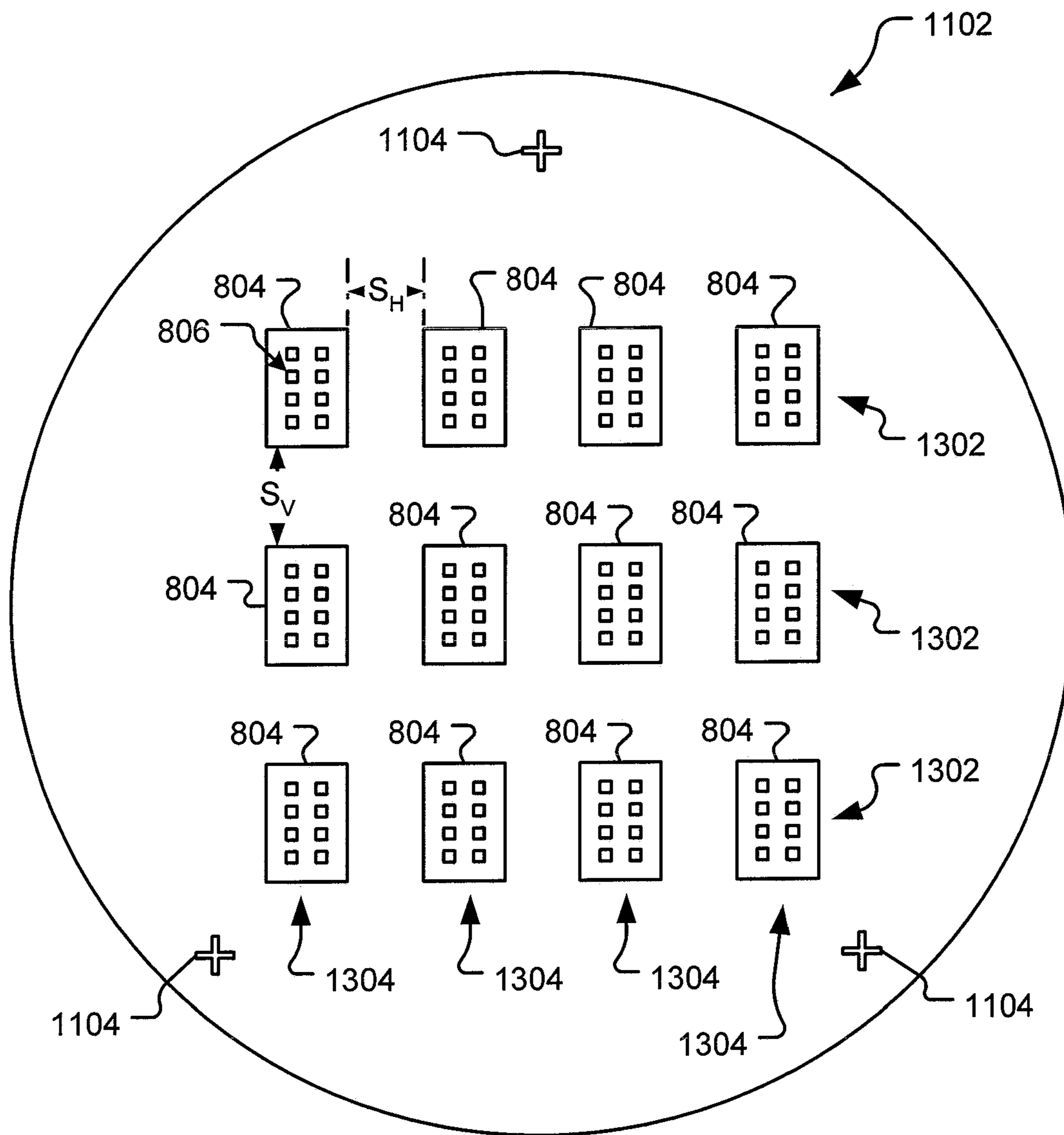


Fig.13

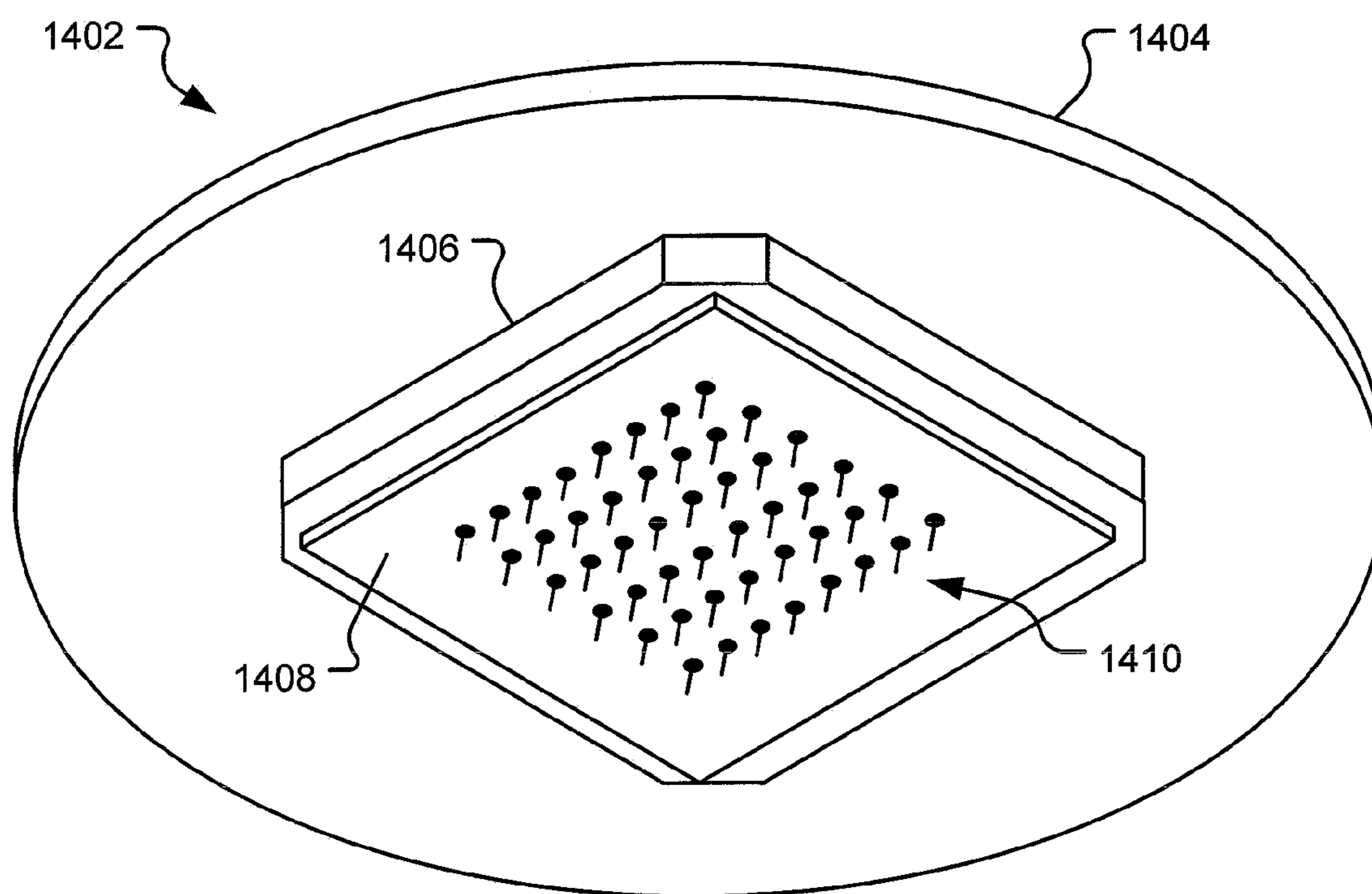


Fig.14



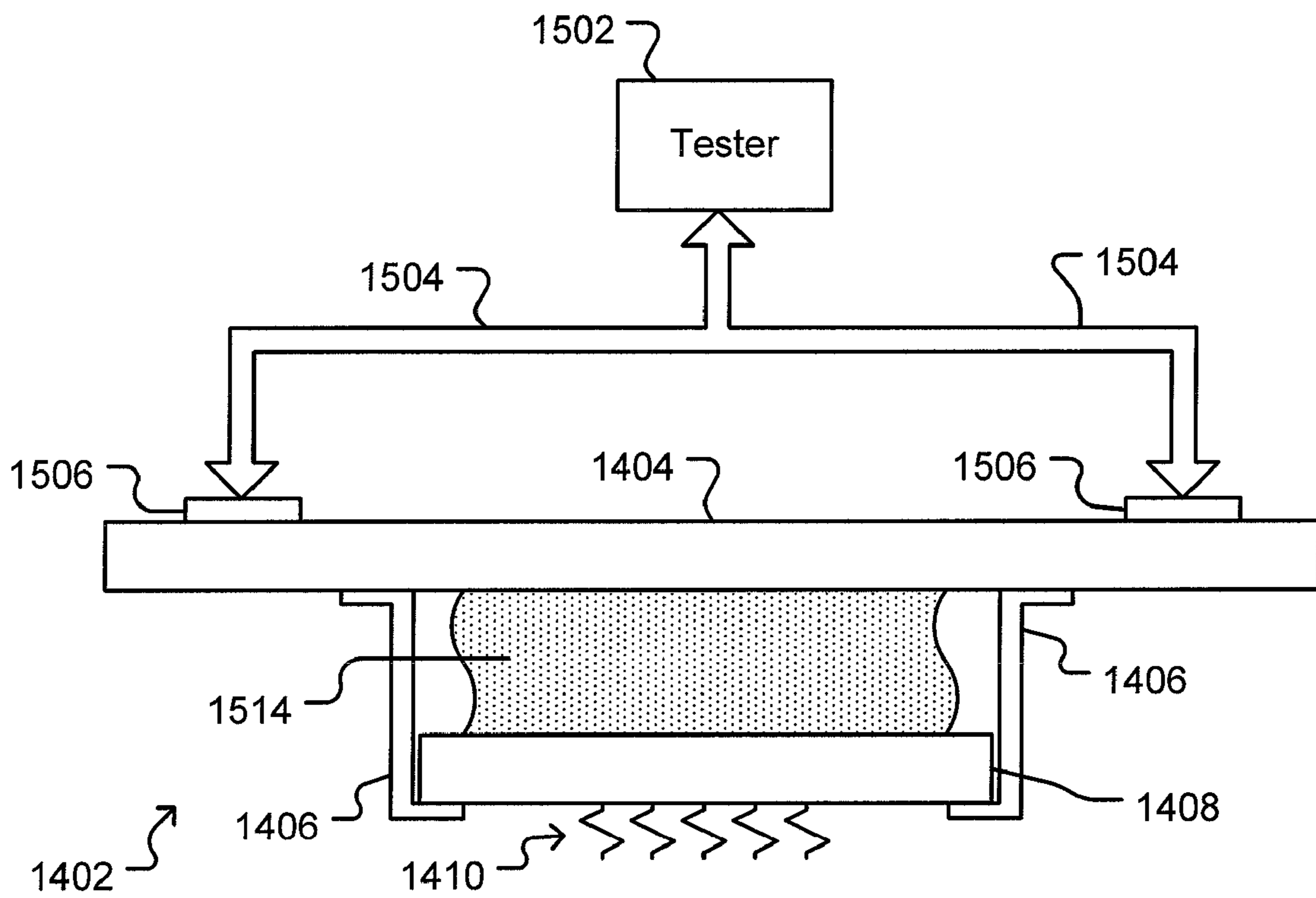


Fig.15

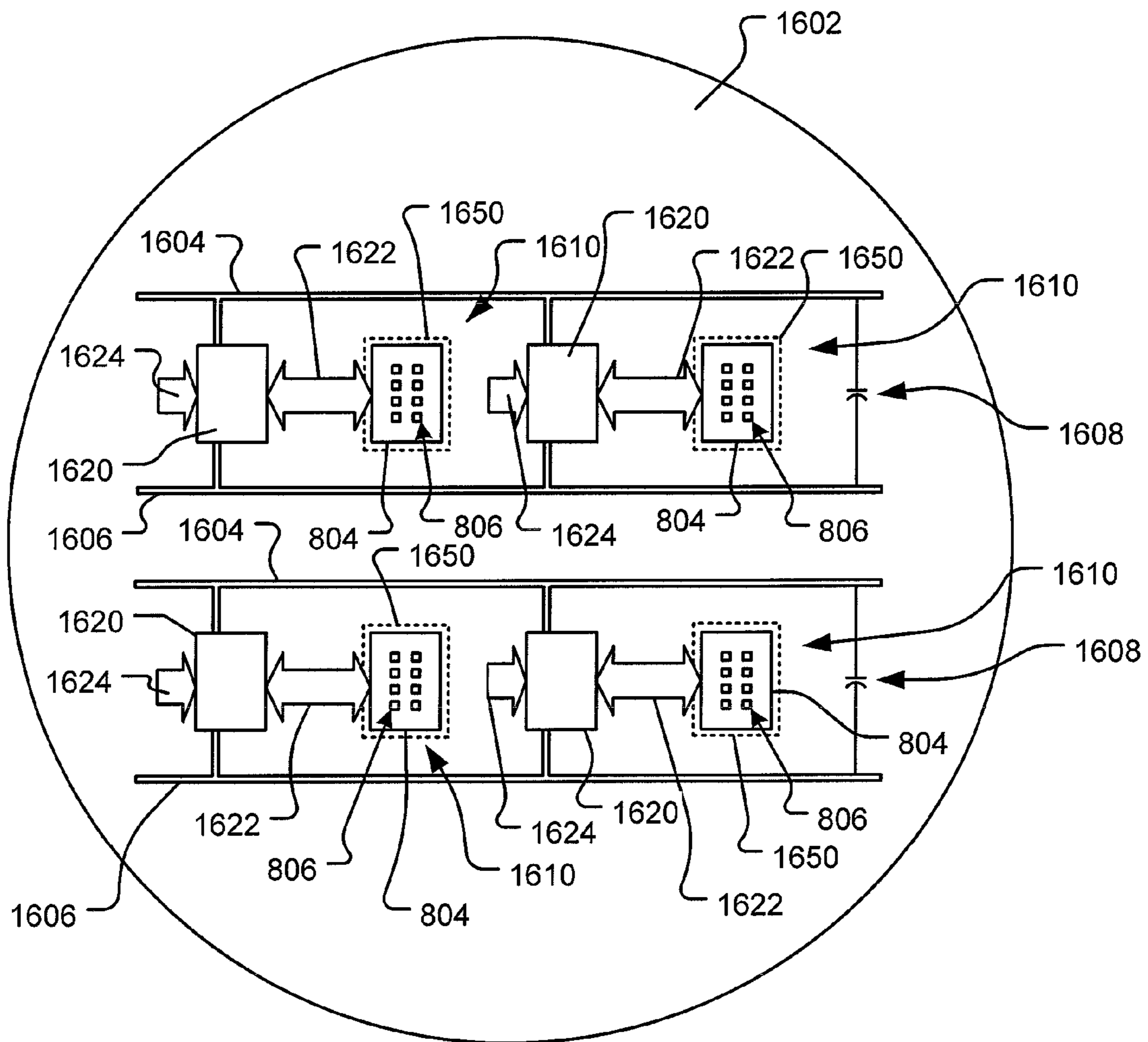


Fig. 16a

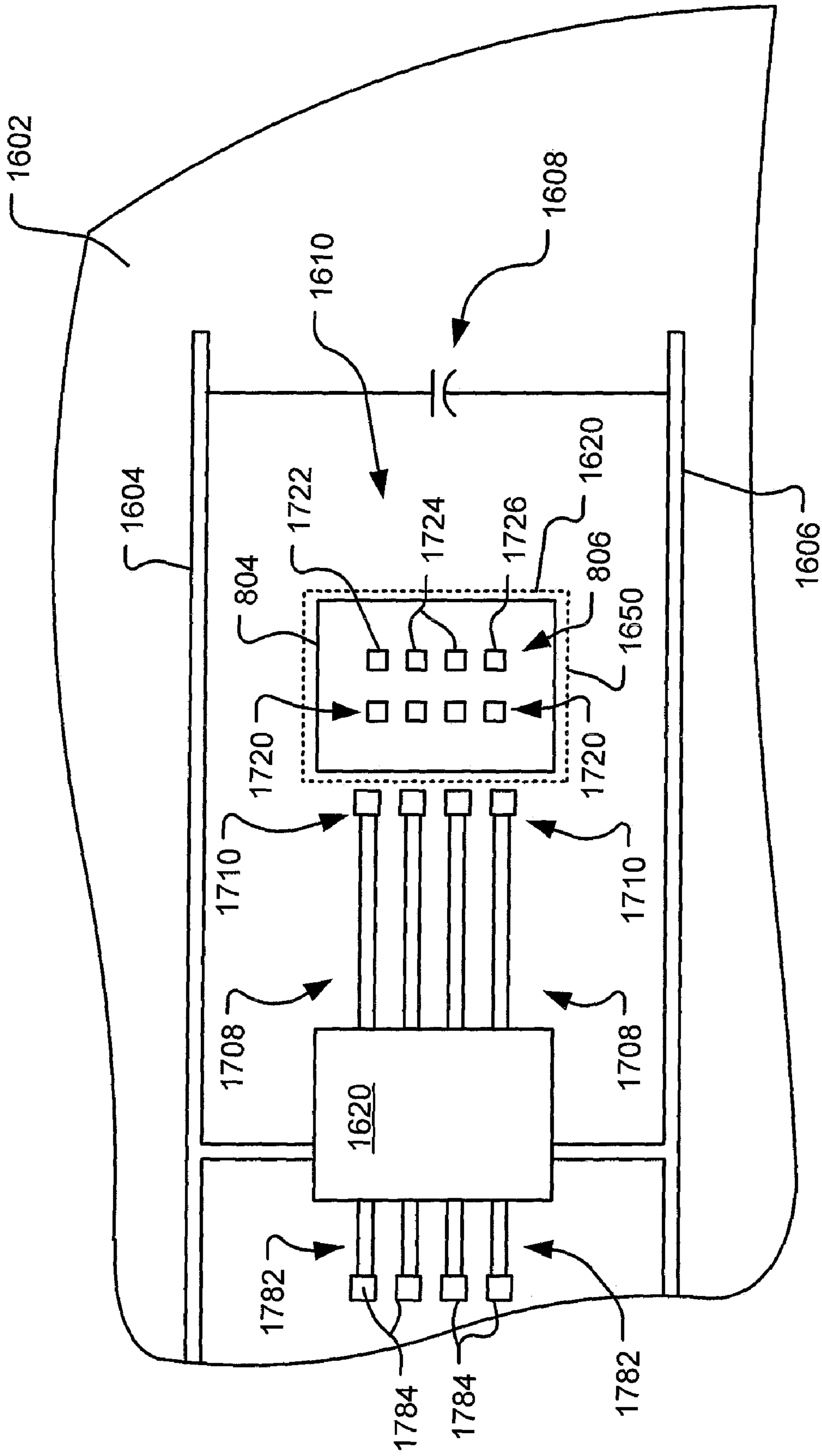


Fig. 16b

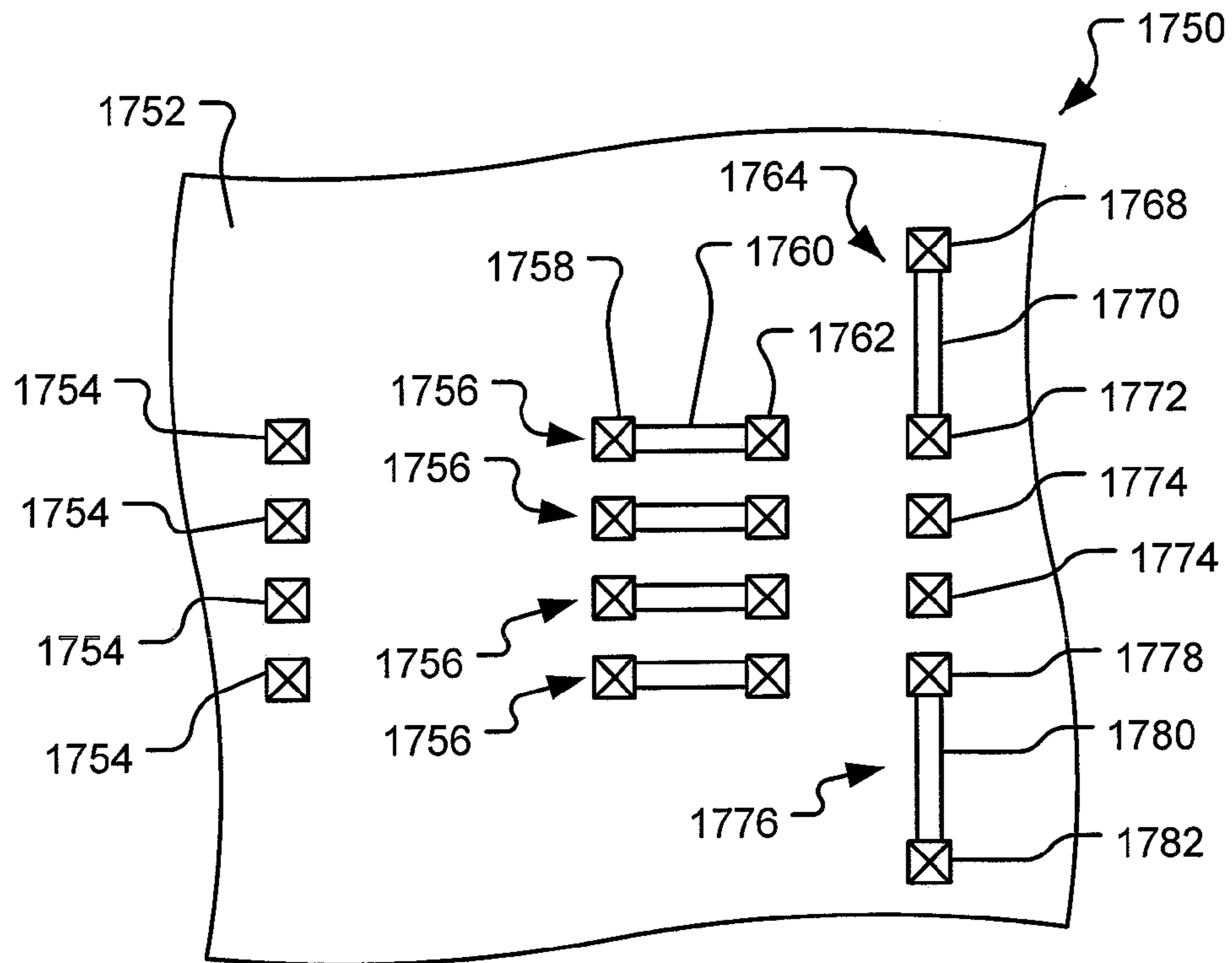


Fig. 17a

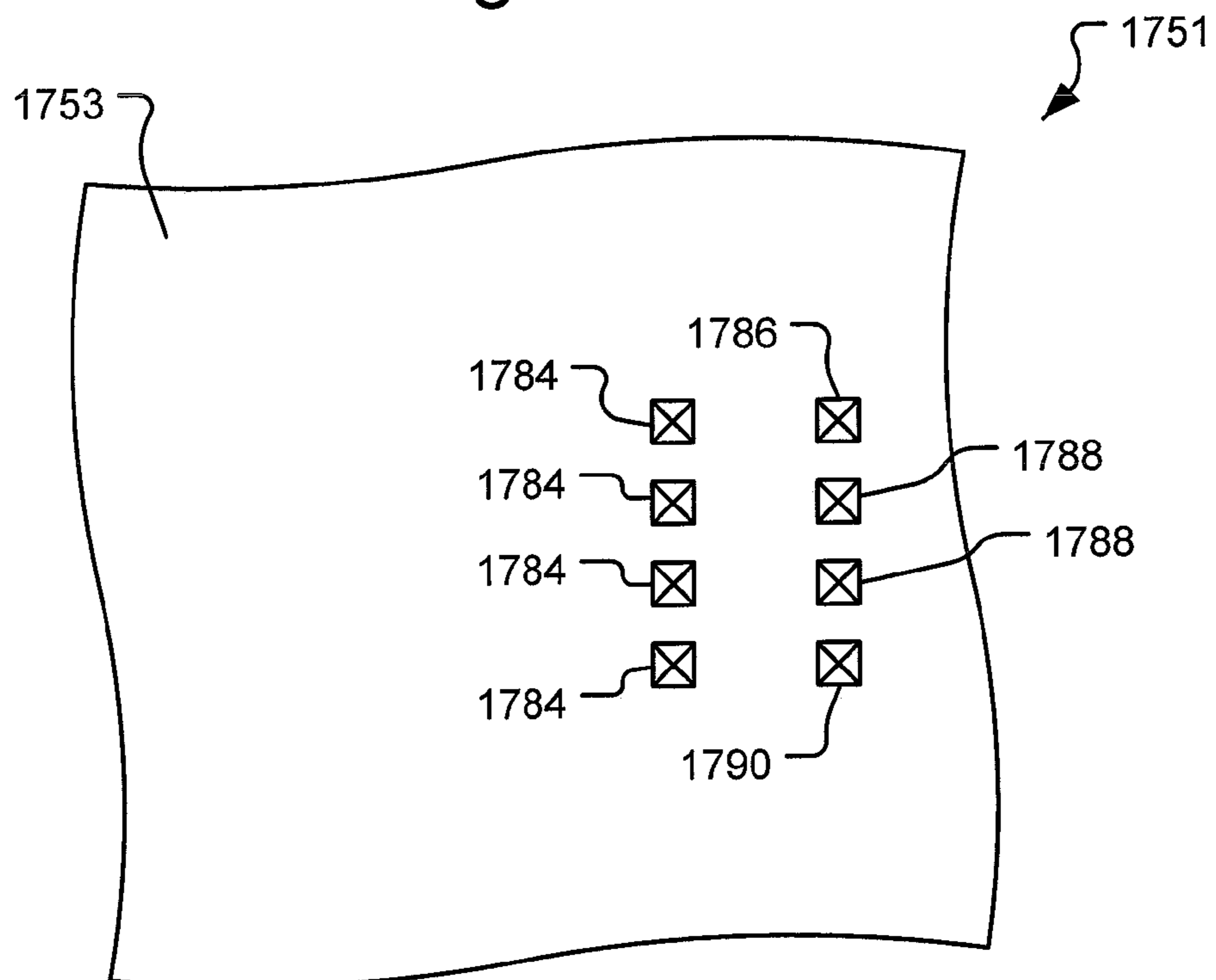


Fig. 17b

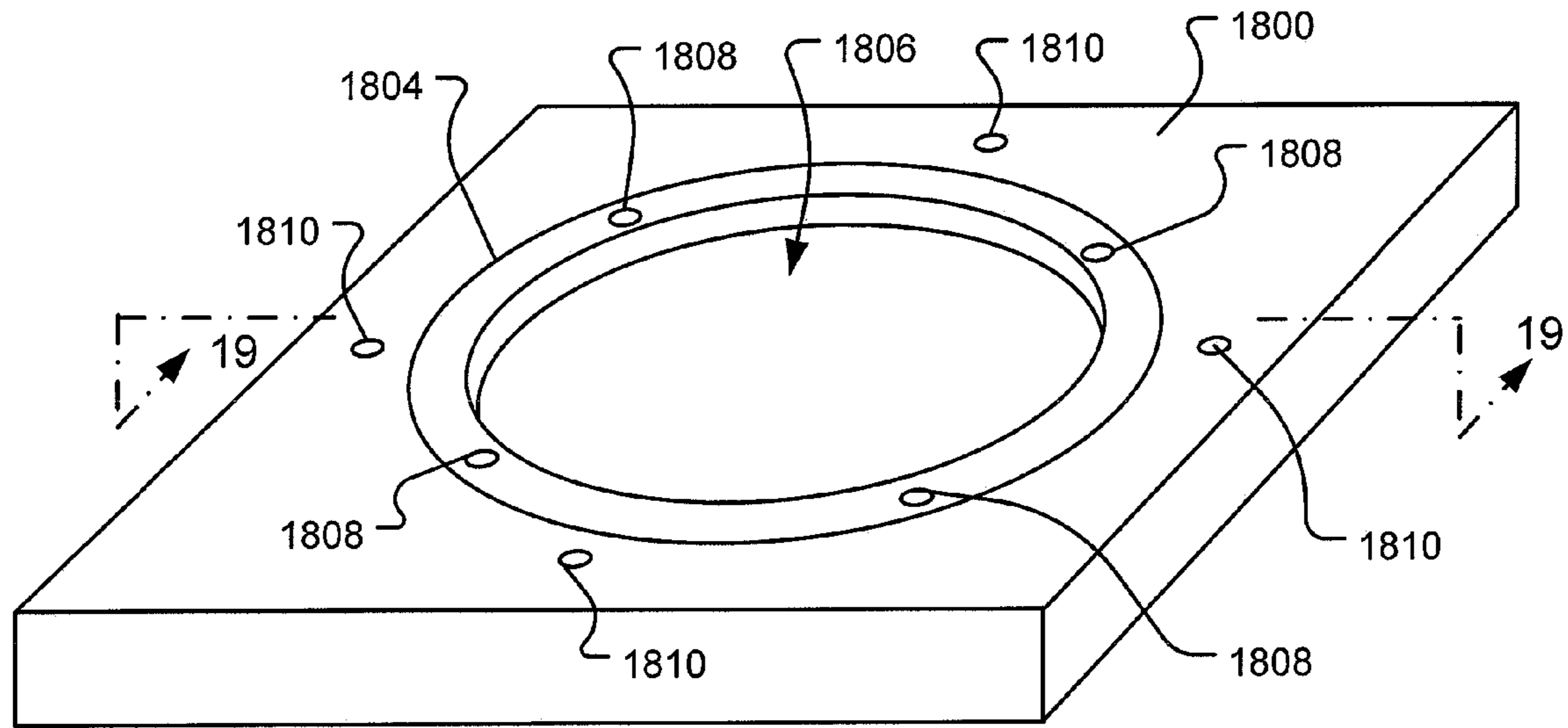


Fig. 18

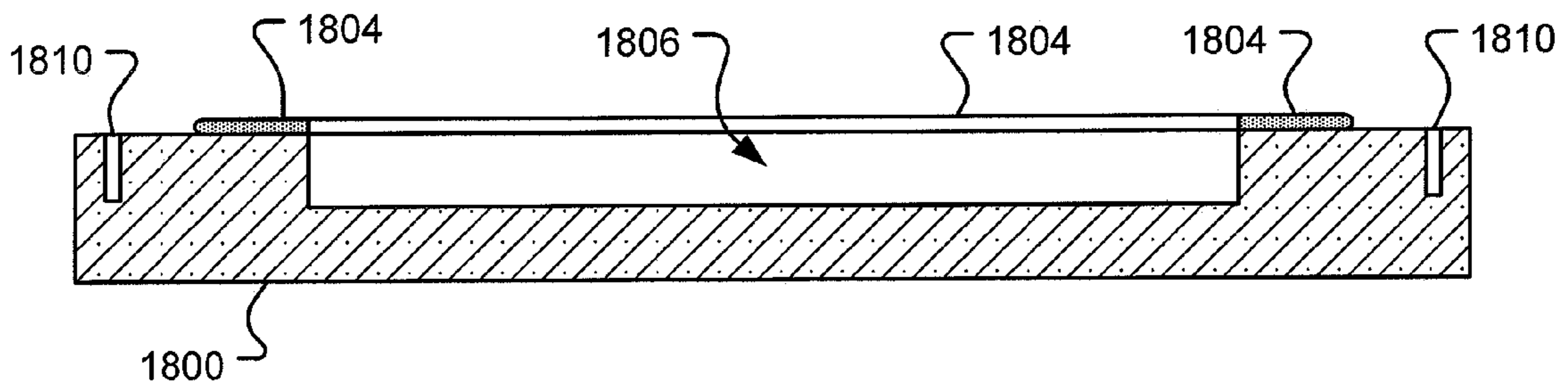


Fig. 19

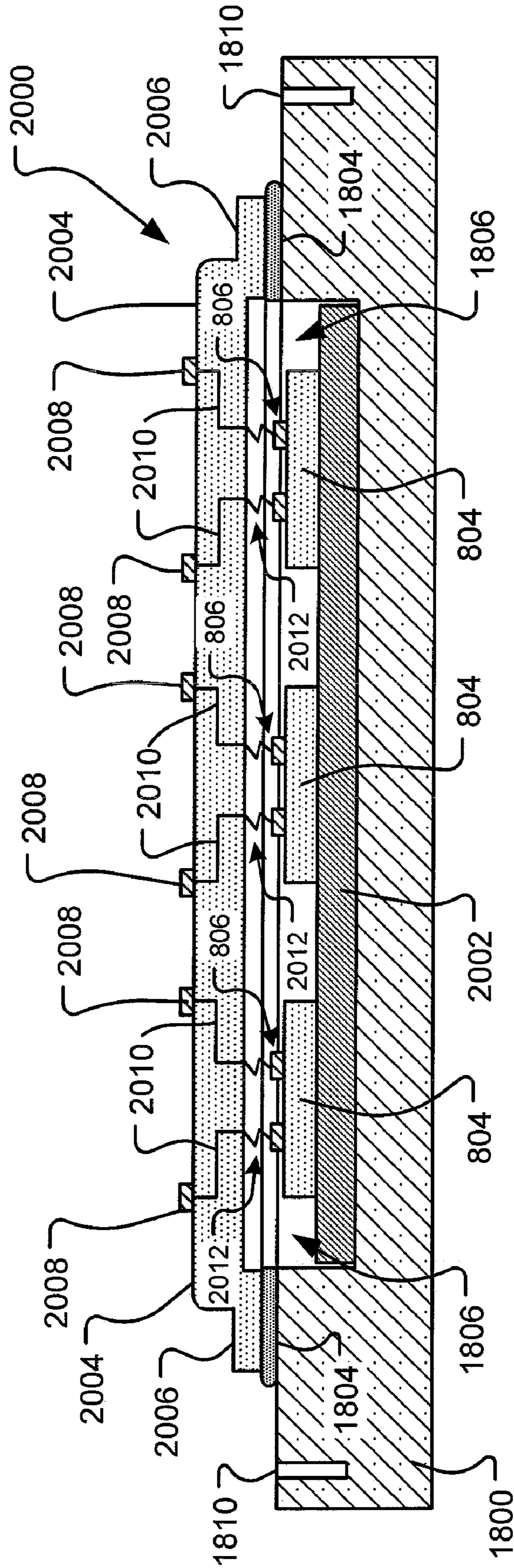


Fig. 20

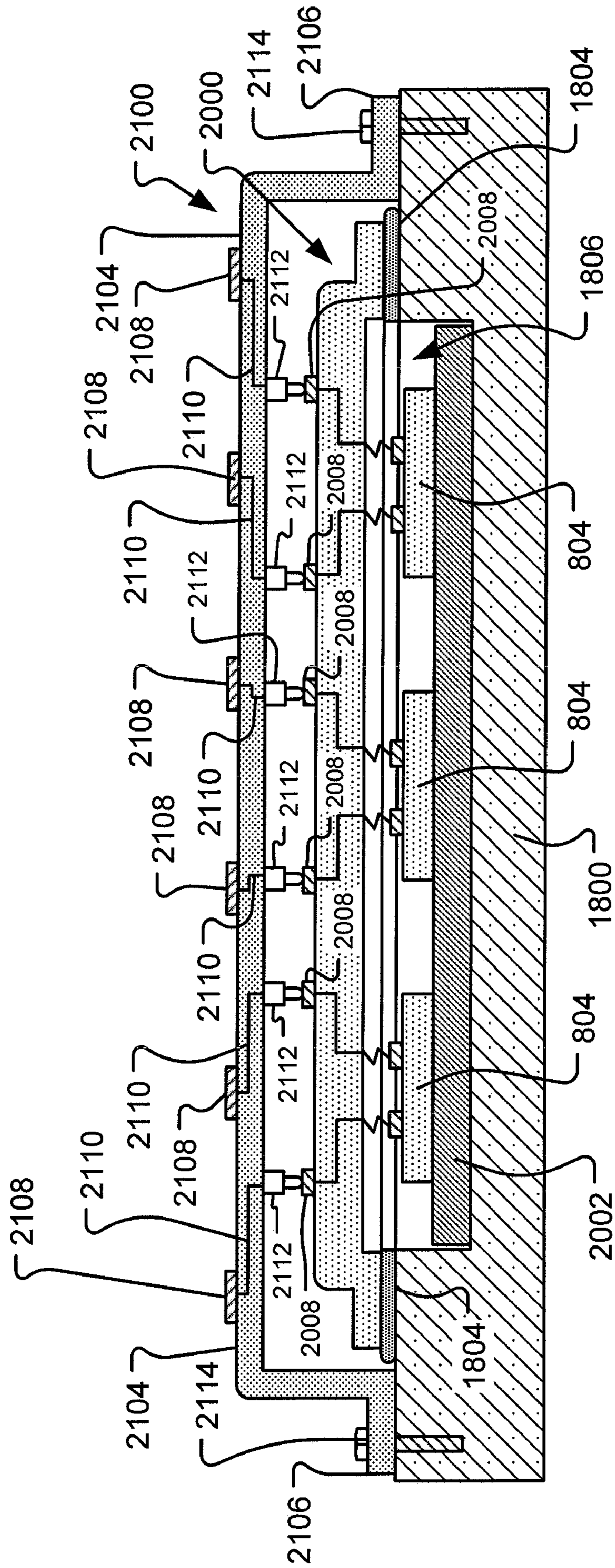


Fig. 21

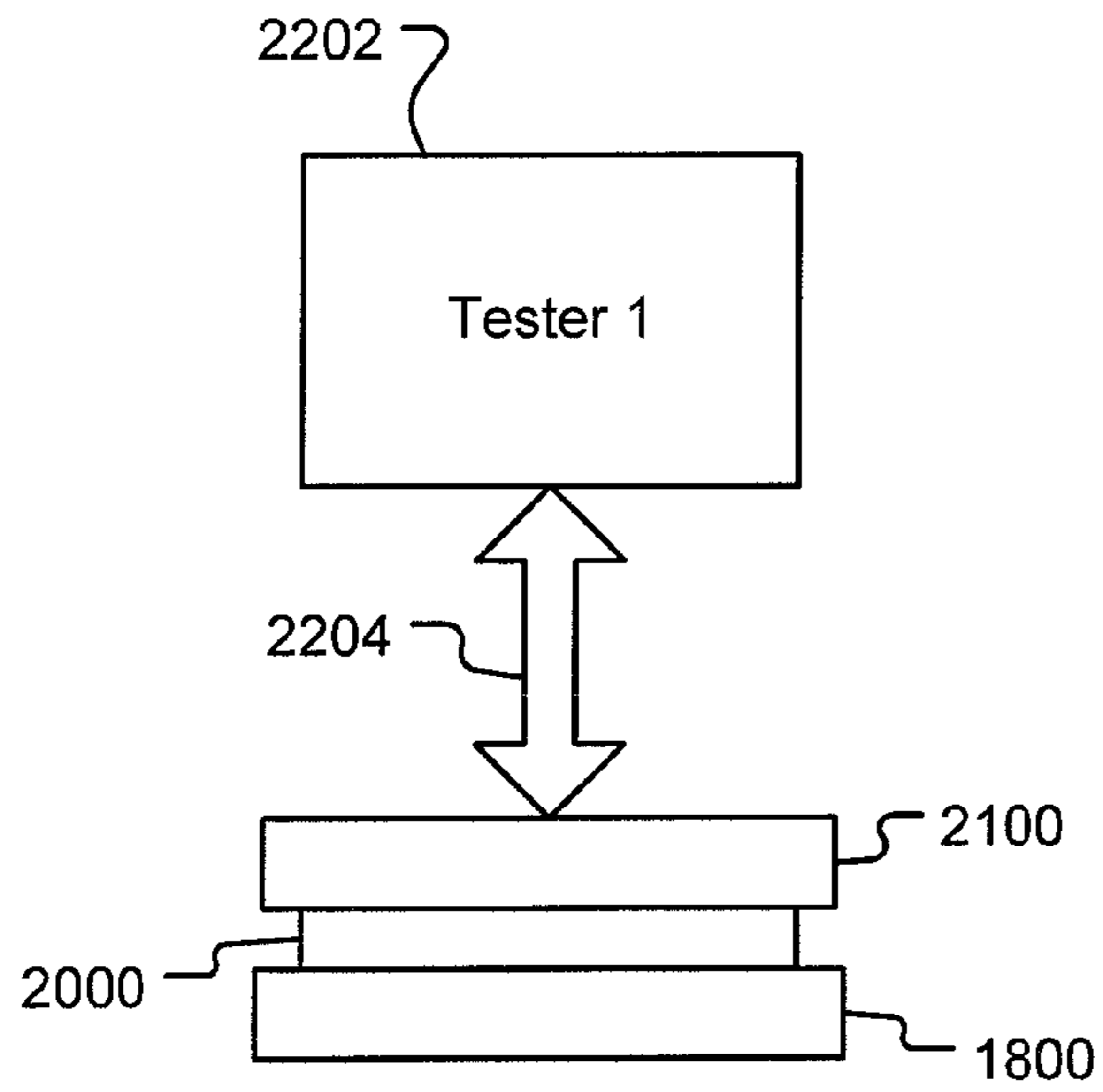


Fig. 22

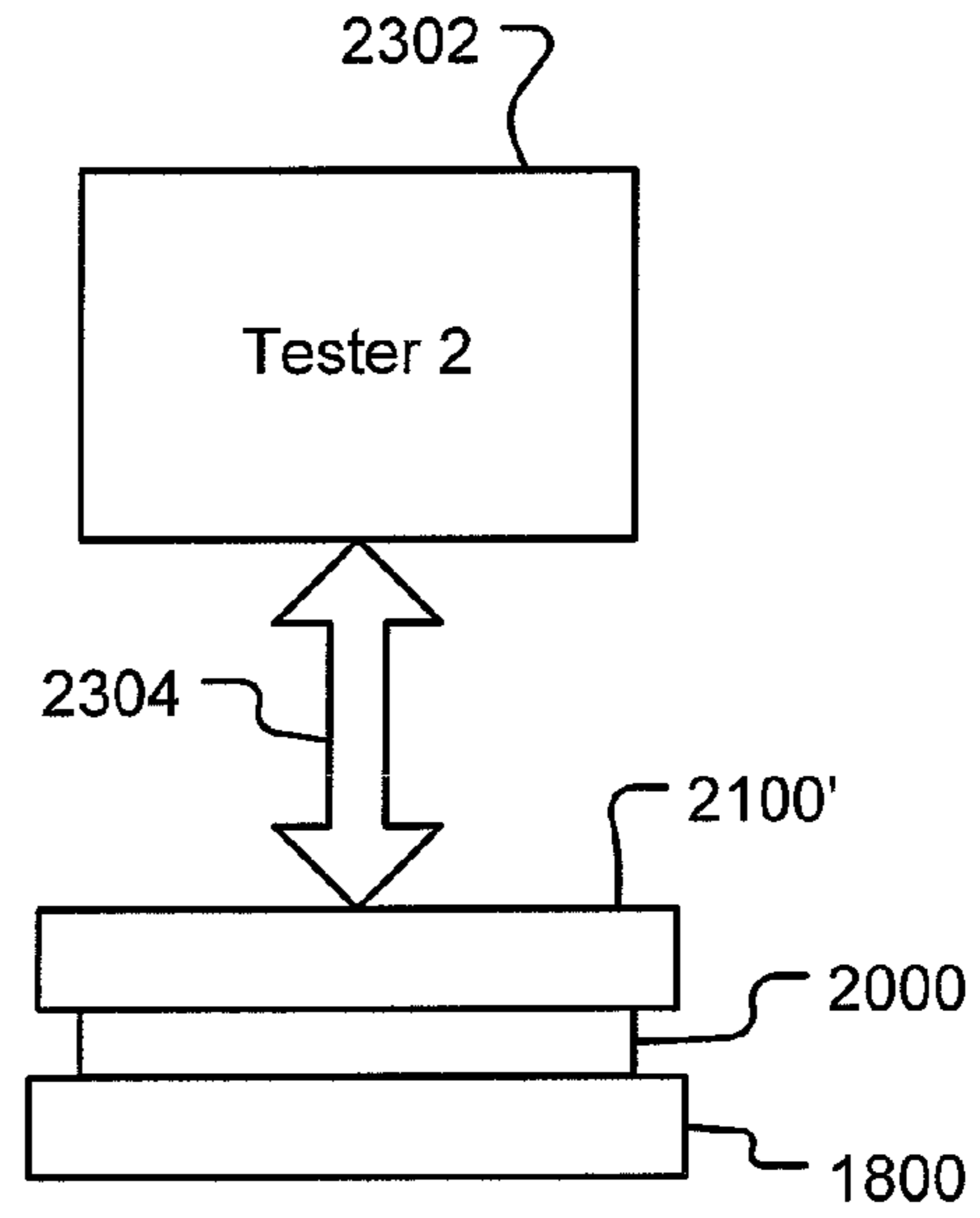


FIG. 23

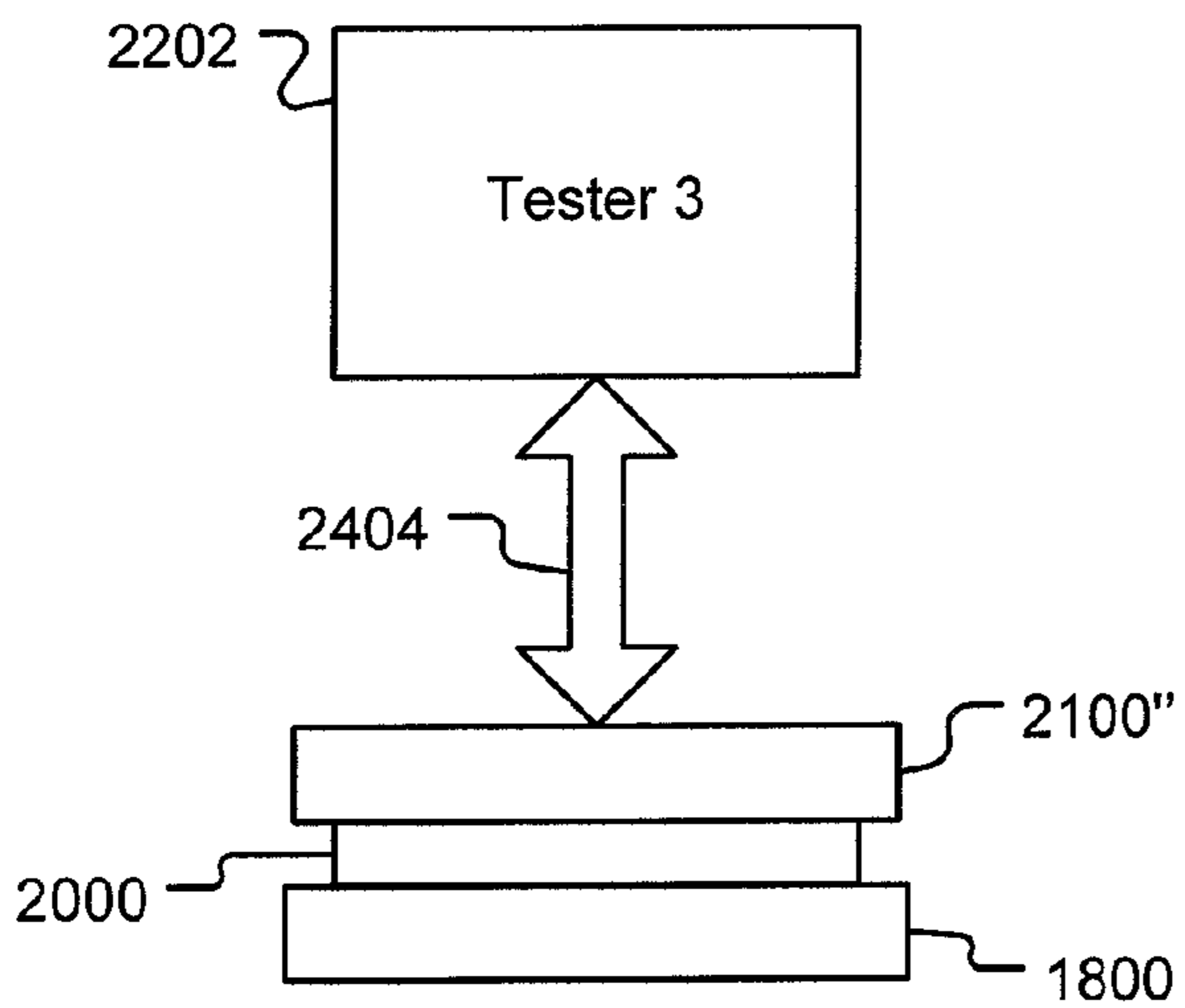


Fig. 24

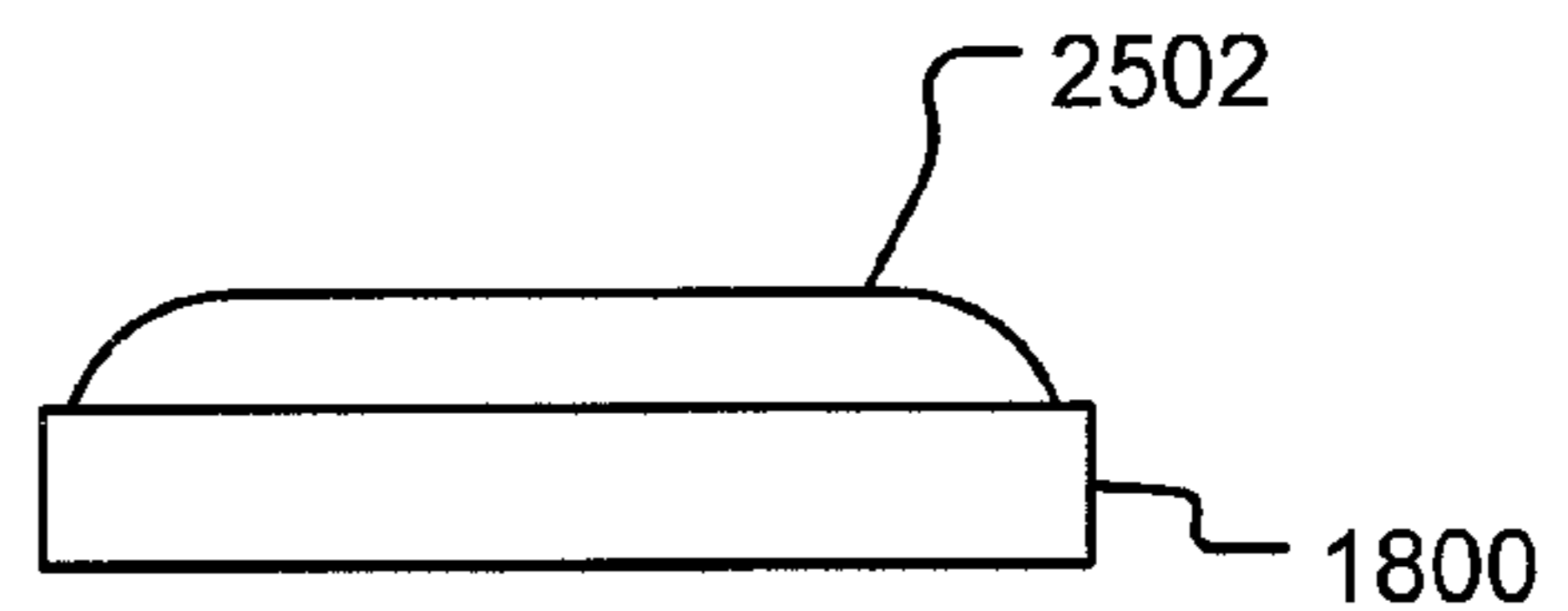


Fig. 25



## 1

## APPARATUS AND METHOD OF TESTING SINGULATED DIES

### CROSS REFERENCE TO RELATED APPLICATIONS

This application claims priority to U.S. Provisional Patent Application Ser. No. 60/718,820, filed Sep. 19, 2005.

### BACKGROUND

Semiconductor devices are typically manufactured many at a time as “dies” on a semiconductor wafer, after which the dies are further processed before being shipped to customers or installed in various products. Semiconductor manufacturing is typically considered to have front end processing, which includes process steps completed at a wafer level and back end processing to handle single die. Thereafter, when the dies are singulated from the wafer, and the dies that passed the initial probe testing are packaged, burned in, and further tested. In another common process, the dies are not packaged after being singulated from the wafer but are further tested and often burned in to produce “known good dies,” which are unpackaged dies that have been fully tested. In more advanced processes, the dies are burned in and fully tested while in wafer form.

### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates an exemplary process for making and testing semiconductor dies according to some embodiments of the invention.

FIG. 2 illustrates an exemplary test system according to some embodiments of the invention.

FIG. 3 illustrates an exemplary carrier substrate according to some embodiments of the invention.

FIGS. 4a-4c illustrate exemplary placement of semiconductor dies on a testing substrate with an intermediate connection device according to some embodiments of the invention.

FIGS. 4d and 4e illustrate exemplary use of dies in stop structures on the testing substrate of FIGS. 4a-4c.

FIGS. 5a-5c illustrate exemplary placement of semiconductor dies on a testing substrate comprising probes with an intermediate connection device according to some embodiments of the invention.

FIG. 6 illustrates an exemplary testing substrate with dies and an intermediate connection device connecting the dies in a testing device according to some embodiments of the invention.

FIG. 7 illustrates an exemplary process for making, testing, and further processing semiconductor dies according to some embodiments of the invention.

FIG. 8 illustrates an exemplary semiconductor wafer on which dies are made according to some embodiments of the invention.

FIGS. 9 and 10 illustrate exemplary wafer level packaging that can be formed on the dies of the wafer of FIG. 8 according to some embodiments of the invention.

FIGS. 11-13 illustrate exemplary placement of dies on a carrier substrate according to some embodiments of the invention.

FIG. 14 illustrates a perspective view of an exemplary probe card assembly according to some embodiments of the invention.

FIG. 15 illustrates a side view of the probe card assembly of FIG. 14.

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FIG. 16a illustrate a top view of an exemplary carrier with test sites comprising test circuitry for testing dies of the wafer of FIG. 8 according to some embodiments of the invention.

FIG. 16b illustrates an exemplary configuration of a test site of the carrier of FIG. 16 according to some embodiments of the invention.

FIG. 17a illustrates a partial view of an exemplary first contactor device that can be used to contact pads and terminals of the test site 1610 shown in FIG. 16b according to some embodiments of the invention.

FIG. 17b illustrates a partial view of an exemplary second contactor device that can be used to contact terminals of the die shown in FIG. 16b according to some embodiments of the invention.

FIGS. 18 and 19 illustrate an exemplary base configured to receive a carrier substrate according to some embodiments of the invention.

FIG. 20 illustrates the base of FIGS. 18 and 19 with a carrier substrate and an intermediate connection device according to some embodiments of the invention.

FIG. 21 illustrates the base, carrier substrate, and intermediate connection device of FIG. 20 with a tester interface device attached to the base according to some embodiments of the invention.

FIGS. 22-24 illustrate the base and intermediate connection device of FIG. 20 with different tester interface devices configured to connect with communication channels from different testers according to some embodiments of the invention.

FIG. 25 illustrates the base of FIGS. 18 and 19 with a cover attached according to some embodiments of the invention.

### DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

This specification describes exemplary embodiments and applications of the invention. The invention, however, is not limited to these exemplary embodiments and applications or to the manner in which the exemplary embodiments and applications operate or are described herein. Moreover, the Figures may show simplified or partial views, and the dimensions of elements in the Figures may be exaggerated or otherwise not in proportion for clarity. In addition, as the terms “on” and “attached to” are used herein, one object (e.g., a material, a layer, a substrate, etc.) can be “on” or “attached to” another object regardless of whether the one object is directly on or attached to the other object or there are one or more intervening objects between the one object and the other object. Also, directions (e.g., above, below, top, bottom, side, vertical, horizontal, “x,” “y,” “z,” etc.), if provided, are relative and provided solely by way of example and for ease of illustration and discussion and not by way of limitation.

Although this invention is generally applicable to test systems and methods in general, it is particularly suited for semiconductor device testing.

Some embodiments of the invention address picking and placing die singulated from a wafer onto a testing substrate. The same testing substrate can be used for a variety of test phases such as high frequency testing, burn-in, and final test. The die can be placed in accordance with a predetermined arrangement that facilitates use in multiple test stations. The arrangement can be selected in accordance with metrics that tend to increase overall tester utilization among the plurality of testers.

Some embodiments of the invention address methodologies for placing the die in arrangements that enhance or facili-

tate certain types of testing. For example, die may be spread out for ease in contacting or arrangement for use with high frequency testers.

According to some embodiments of the present invention, and referring to FIG. 1, semiconductors are initially fabricated as an array of die on a semiconductor wafer at **102**. The wafer can be subjected to wafer level testing at **104**. The types of wafer level testing can include testing the die on the wafer for parametric tests in which, for example, the current drawn at the dies' power terminals are measured. In some instances, a laser repair system can process memory test data (in the case of dies which are memories) to determine which of embedded memory rows or columns contain defective cells, determine how to allocate spare rows and columns to repair the memory, and then employ a laser to repair any defective memories. After repairing defective memories, the memories may be again tested while the die are still at the wafer level to ensure that the repair was effective. The die can also be subjected to additional logic or parametric testing at this point, such as functional, open/short, leakage, and AC/DC. Various of these tests can be performed at the wafer level and at various places in the manufacturing. The testing at **104** can associate an identification of the die according to the die's performance on the specific test. For example, some die may be identified as being non-functional and beyond repair, as repairable, or having certain characteristics based on the tests performed. As another example some die may be identified as having shorts, that is, connections between power and ground with little resistance. In some instances the identification of the die according to the various test results can be presented as a wafer map. Selected die can be identified for subsequent testing at **106**. The identification process can be based on various types of selection criteria. In general, bad die (as determined by various criteria) are determined early in the testing process so further test resources or processing steps, including steps such as packaging and final test, are not used to test die known to be bad for the intended purpose or as compared against the selection criteria.

The die can then be singulated from the wafer at **108** by various methods. In some embodiments, the wafer is flipped over and placed against a film substrate which holds the wafer in place such that the back side of the wafer is facing upward. The back side of the wafer can be ground down to a specific thickness. A saw can cut the die from the wafer along predetermined paths leaving the die on the film. Other methods can be used to result in singulated die which may or may not be presented on a film substrate.

Regardless of the singulation method, the die can then be picked up from the film or other source of singulated die and individually manipulated by a manipulation system and placed in another location at **110**. The manipulation system can produce a die in an active side up or active side down presentation for subsequent placement. It is sufficient that the manipulation system be able to pick up a die and place it in a known location in a known orientation on a surface. In some embodiments, the die can be placed on a testing substrate from which the die can be subjected to further testing of various types at **112**. The surface can be a chuck as found in a probing device as described below. The surface can also be a carrier substrate that can be placed on a prober chuck. The carrier substrate can be moved to and/or be adapted for use with different probers and/or different testing stations. The carrier substrate can include means for securing the die in place and/or means for electrically connecting to the die. The manipulation system can be part of or used in conjunction with a prober. Singulated die chosen according to predetermined criteria (such as those which have passed initial wafer

testing) can be positioned on the testing substrate by the manipulation system. Singulated die can be placed in reference to the circuitry and/or location of contact pads or other identifying marks on the die rather than the edges of the die. The die can be placed with reference to a landmark on the surface and/or in reference to each other.

FIG. 2 illustrates a probing system **200** according to some embodiments of the invention. A prober **202** (which can include a prober housing) includes a chuck **204** and a chuck positioning means **206**. The prober can also include a probe card **208**. The prober **202** can also include a manipulation system **210**. A test head **212** can connect with the probe card **208**. The test head **212** can be connected to a tester **214** (e.g., a source of test signals) via a connection **216**. Connection **216** can be of various types (e.g., wireless, wired, optical, etc.). Although illustrated as separate components one or more of the components described above can be combined with one or more other components. For example, the manipulation system **210** may be part of the prober **202** or it may be a stand-alone component.

According to some embodiments of the invention, a manipulation system, such as manipulation system **210** can pick a die from a singulated die source **218** and place it on a prober chuck **204**. The manipulation system can comprise, for example, a robotic mechanism (e.g., a robotic arm) configured to pick up a die and place the die at a desired location. Such pick-and-place machines are well known, and any such machine can be used. The singulated die source **218** can contain previously singulated die or a wafer singulation apparatus. The singulated die source may be connected to the prober or stand alone from the prober **202**. The die can be held in place by various techniques such as by a vacuum, various types of adhesives, or by electrostatic charges. The prober chuck **204** can include means for maintaining an electrostatic charge. It is sufficient that the die be held in place while the chuck is moved from one position to another.

As mentioned earlier the die can be placed on a carrier substrate (such as carrier substrate **300** in FIG. 3). The carrier substrate can be substantially planar. The carrier can be provided without the use of recesses. Although shown in an elliptical shape, the carrier substrate **300** can be other shapes as well (such as circular or rectangular). The carrier substrate **300** can include means to hold the die in place such as by a vacuum, various types of adhesives, or by electrostatic charges. The carrier substrate can include means for maintaining an electrostatic charge (e.g., a battery or electrical connection). It is sufficient that the die be held in place while the carrier substrate is moved from one position to another. The carrier substrate can be populated with die by the manipulation system **210** or by other means. For example, the carrier substrate **300** can be populated by another apparatus. The carrier substrate **300** can be adapted for use with more than one type of tester, chuck, test station, probe card and the like.

Referring back to FIG. 2, once the desired number of die (such as die **220**) are placed on the chuck **204** in desired positions, the chuck **204** may be moved into position for testing of the die such as by movement to a predetermined position relative to a probe card **208**. For example, terminals of ones or all of the die **220** can be brought into contact with ones or all of probes **222**. Alternatively, a populated carrier substrate **300** can be placed on the chuck and the chuck moved to the desired location. The carrier substrate **300** can be populated with die by the probing system **200** (e.g., manipulation system **210**) or by other means and received in a populated state by the probing system **200**.

The probe card can include various types of probes **222** used to establish electrical connection to the individual die **220** (such as bumps, elongate resilient connections, lithographic springs, needle probes, probes tips including truncated pyramids and so on). In some instances electrical connection to the die can be by capacitive coupling (in which case mechanical connection to the die can be eliminated). The connections can also include a combination of mechanical and capacitive coupling to make electrical connection with the die. The die **220** may be tested in parallel as they would if they were still part of the wafer. For example, if the probing system **200** is not able to test all die at the same time, the chuck can be moved to test a predetermined number of die at each position relative to the probing device.

In some embodiments, an intermediary connection device can be placed on the die such as a land grid array (LGA) of conductive pads, a connector or other types of electrical contacts. Referring to FIG. **4a**, a testing substrate **400** (such as a chuck **204** or a carrier substrate **300**) is illustrated in an unpopulated state. Referring to FIG. **4b**, one or more die **402** are positioned on the testing substrate **400**. The die **402** can be placed by the manipulation system **210** for example, or other means. It should be noted that FIGS. **4a** and **4b** are similar to die placement as described in reference to FIG. **2**. Referring to FIG. **4c**, an intermediate connection device **404** can be positioned over the die **402** such that probe elements **406** on a substrate **408** are aligned with pads on the die **402**. Optionally, one or more compression stops **410** can be provided as part of the intermediate connection device **404** or on the testing substrate **400** to prevent over-compression of the probes **406**. Compression stops **410** can be any type of structure that limits movement of the substrate **408** towards the testing substrate and thereby defines a minimum spacing between the substrate **408** and the testing substrate **400**. Examples of compression stops **410** include posts, bumps, or any other structure that is sufficiently rigid, sturdy, and/or strong to stop movement of the substrate **408** toward the dies **402** (see FIG. **4c**) and thus limit compression of probes **406**. Probes **406** can extend from substrate **408** by a distance that is greater than the height of the compression stops **410**. Consequently, while intermediate connection device **404** is disposed on the compression stops **410**, the probes **406** can be compressed against—and thereby form electrical connections with—the dies **402** (e.g., input and/or output terminals (not shown) of the dies **402**).

FIGS. **4d** and **4e** illustrate another non-limiting example of compression stops **410** according to some embodiments of the invention. FIG. **4d** illustrates a partial, perspective view of the testing substrate **400** of FIGS. **4a-4c**, showing some of the dies **402** (e.g., first dies) that are to be tested and two exemplary stop structures **452**, although more or fewer can be used. As shown, compression stops **410** can comprise a stop structure **452** and a die **450**, which can be a bad die (e.g. a die that failed any previous inspection or testing, such as testing at **104** of FIG. **1**, or as will be seen, testing at **704** of FIG. **7**). Stop structures **452** can comprise posts, bumps, or any other structure that is sufficiently rigid, sturdy, and/or strong to stop movement of the substrate **408** toward the dies **402** (see FIG. **4c**). As shown in FIGS. **4d** and **4e**, dies **450** (e.g., second dies) can be placed onto stop structures **452**. The dies **450** can be placed onto and held in place on the stop structures **452** using any technique disclosed herein for picking, placing, and/or holding dies in place.

The dies **450** can be dies that were manufactured on the same wafer as the dies **402** placed on the testing substrate **400** to be tested, in which case, the dies **450** will have approximately the same thickness as the dies **402** to be tested. Even if the dies **450** are from a different wafer but are nevertheless

from the same manufacturing lot or batch or even from the same manufacturing process as the dies **402** to be tested, the dies **450** can have approximately the same thickness or at least a somewhat similar thickness as the dies **402** to be tested.

FIG. **4e** illustrates a non-limiting advantage of a compression stop **410** that comprises a stop structure **452** with a fixed height  $H_1$  and a die **450** whose thickness  $T_2$  is the same as, approximately the same as, or generally similar to the thickness  $T_1$  of the dies **402** to be tested. As should be apparent from FIG. **4e**, if the compression stop **410** consisted solely of the stop structure **452**, the effective height of the compression stop **410** would be the height  $H_1$  of the stop structure **452** less the thickness  $T_1$  of the dies **402** to be tested, which as can be seen, can vary with the thickness  $T_1$  of the dies **402** to be tested. Thus, the greater the thickness  $T_1$  of the dies **402** being tested, the more the probes **406** (see FIG. **4c**) would be compressed while intermediate connection device **404** is disposed on stop structures **410**. Likewise, the less the thickness  $T_1$  of the dies **402** being tested, the less the probes **406** (see FIG. **4c**) would be compressed. Thus, the effective height of the compression stop **410** and therefore the level to which the probes **406** are compressed while substrate **404** is disposed on the compression stops **410** (see FIG. **4c**) would vary with the thickness  $T_1$  of the dies **402** being tested.

Configured as shown in FIG. **4e**, however, the effective height and therefore the level to which the probes **406** are compressed while substrate **404** is disposed on the compression stops **410** (see FIG. **4c**) can be made to vary less or not at all even as different dies **402** with different thicknesses  $T_1$  are placed on testing substrate **400** and tested. This is because the die **450** adds its thickness  $T_2$  to the overall height  $H_O$  of the compression stop **410**. As long as the thickness  $T_2$  of the die **450** is the same as, approximately the same as, or similar to the thickness  $T_1$  of the dies **402** to be tested, the effective height of the compression stop **410** will be or will approximately be the height of the stop structure  $H_1$ . Thus, as testing substrate **400** is used over time to test different types of dies **402** with different thicknesses  $T_1$ , and as different corresponding dies **450** with the same or similar thicknesses are used in compression stops **410** as shown in FIGS. **4d** and **4e**, the effective height of the compression stop **410** and therefore the level to which the probes **406** are compressed while substrate **404** is disposed on the compression stops **410** (see FIG. **4c**) will be the same or approximately the same and will generally not vary with the thickness  $T_1$  of the different types of dies **402** tested.

Regardless of the particular structure or configuration of the compression stops **410**, the compression stops **410** can also provide a planarization function for the intermediate connection device **404**. That is, the compression stops can be set at heights such that when the intermediate connection device is compressed from above, it becomes more planar. The compression stops **410** can be designed to be adjusted to different heights while connected to the intermediate connection device **404** and/or the testing substrate **400**. The probes **406** can be similar to the probes **222**. The intermediate connection device **404** can be placed by the manipulation system **210** for example. The intermediate connection device **404** can be placed by other mechanisms. When using a carrier substrate **300** as the testing substrate **400**, the assemblies illustrated in both FIGS. **4b** and **4c** can be assembled by or separately from the probing system **200** and/or can be moved from one location to another such as different test locations, stations, probers, and so on. The intermediate connection device **404** can provide electrical connection from the probes **406** to the upper surface of the intermediary connection device **404**.

The connection on the upper surface of the intermediate connection device **404** can be at a pitch greater than the probe **406** pitch.

In some embodiments, the compressive force of intermediate connection device **404** on die **402** provides enough force that the die **402** need not be held in place on the testing substrate by any other means. The die can be placed on the testing substrate **400** without means to hold the die in place after which the intermediate connection device **404** is placed on the die **402**. Alternatively, the holding means (such as a vacuum or electrostatic) can be used to hold the die **402** until the intermediate connection device **404** is placed on the die **402** after which the holding means can be removed or disabled.

Although illustrated as a single intermediate connection device **404**, a plurality of intermediate connection devices can be provided each contacting one or more of the die **402**. Each of the plurality of intermediate connection devices can be individually placed. A plurality of intermediate connection devices can reduce the requirement for a single intermediate connection device of large area. Some materials may suffer from warping as the surface area becomes large.

The intermediate connection device **404** can be adapted to provide an interface from a probe card and/or test head such that the assembly of FIG. **4c** can be moved into position to test the die **402** using the probe card and/or test head. For example, when the testing substrate **400** is chuck **204**, the assembly can be moved in relative position to the probe card **208** such that the probes on the probe card contact the contacts on the upper surface of intermediate connection device **404**. Alternatively, the assembly can be moved in relative position to the test head **212** for connection directly with the test head **212**. One or more interfaces can be provided between the intermediate connection device **404** and the test head **212**.

Different intermediate connection devices **404** can be adapted for different phases of testing. For example, one intermediate connection device **404** can be adapted for burn-in testing and another for high frequency testing. The intermediate connection device **404** can be chosen based on the desired test. Intermediate connection devices **404** can be replaced from one testing station to another. For example, an intermediate connection device **404** designed for burn-in testing can be removed after burn-in testing and replaced with one designed for high frequency testing prior to high frequency testing. Intermediate connection devices **404** can also be adapted for different test heads, probe cards and the like. In some embodiments, the intermediate connection device **404** provides a standardized platform to electrically connect to the die below. Accordingly the same intermediate connection device **404** can be used with different types of testing devices. The testing devices need only understand how to interact with the connection surface of the intermediate connection device **404**. One or more additional interconnection mediums can be provided between the interconnection device **404** and a connection surface to be contacted by a probe card and/or test head.

The testing substrate **400** can include a storage means **412**. The storage means **412** can store information identifying particular die **402** and their test results and/or identification (such as originating wafer location). The storage means **412** can include processing circuitry.

The testing substrate **400** can include environmental control means **414** which can be used to control the environmental conditions of the testing substrate **400** (such as heating or cooling). The environmental control means **414** can include processing circuitry. Alternatively, the testing substrate can be adapted to interface with an environmental control system.

Once the probes **406** of the intermediate connection device **404** are brought into contact with the dies **402** as shown in FIG. **4c**, which, as shown, can include disposing the intermediate connection device **404** on the compression stops **410**, test signals can be provided from a tester (not shown in FIG. **4c**), such as tester **214** (or any other tester disclosed herein), through the intermediate connection device **404** and probes **406** to the dies **402**. Response signals generated by the dies **402** in response to the test signals can be sensed by probes **406** and provided to the tester through the intermediate connection device **404**. The tester can then analyze the response signals to determine if the response signals are as expected and thus whether individual dies **402** passed or failed the testing.

FIGS. **5a-5c** illustrate alternative embodiments. Referring to FIG. **5a** a testing substrate **500** (such as chuck **204** or carrier substrate **300**) includes probes **502** (similar to probes **222** described above). Electrical connection can be provided from the probes **502** to locations on the testing substrate **500**. For example, the testing substrate **500** can include contact pads on the surface opposite the surface to which the probes **502** are attached. Alternatively, electrical pathways from the probes **502** to other locations on testing substrate **500** can be provided. The electrical pathways can provide a connection for the test signals to reach the probes **502** from the tester interface to testing substrate **500**. Die **504** can be aligned and placed, active side down, on probes **502**. Gravity can hold the die **504** in place on the probes **502**. Test signals can be provided via the electrical pathways to test the die **504**. Optionally, a weight **506** can be provided as illustrated in FIG. **5c** to increase the compression force between the surface of the die **604** and the probes **502**. Optional compression stops **508** can be provided on the testing substrate **500** and/or weight **506** to prevent over-travel of the probes **502** due to the compressive force on the die **504**. The compression stops **508** can be designed to be adjusted to different heights while connected to the weight **506** and/or the testing substrate **500**. Compression stops **508** can be like compression stops **410**. When the testing substrate is a carrier substrate **300** the assemblies of FIGS. **5b** and **5c** can be assembled by or separately from the probing system **200** and/or can be moved from one location to another such as different test locations, stations, probers, and so on.

FIG. **6** illustrates an assembly of FIG. **4c**, where the testing substrate **400** is a carrier substrate **300**, as part of a larger carrier assembly **600**. Items numbered similarly to those of FIG. **4** can be as previously described. The assembly **600** can include sidewalls **602** which can be formed separately from or integral with the testing substrate **400**. The assembly can optionally include stops **604** which can be used in conjunction with or in place of compression stops **410**. Stops **604** can provide a mechanical ledge upon which the intermediate connection device **404** can be placed. A top **606** can also be provided. The top **606** can provide electrical connection from points on the upper surface of the intermediate connection device **404** to an outer surface the top **606**, such as the upper surface. A testing device **608** (such as a probe card and/or test head) can connect with the top **606** to effect testing of the die **402**. The top **606** can also be used when transporting the assembly from one location to another and removed to allow a testing device to connect with the intermediate connection device. The assembly can be adapted to provide degrees of environmental isolation for the inside of the assembly such that the assembly can be populated with die in a room of one degree of cleanliness and, after closure, moved to another room of different cleanliness while preserving the initial cleanliness for the die. For example, the die can be placed into

the assembly 600 in a clean room (e.g., a class 10 room) and moved to another room for testing (e.g., a class 1000 room) without exposing the die to the dirty environment.

The die can be placed on the testing substrate 400 (such as chuck 204 and/or carrier substrate 300) according to various desired criteria. For example, the die can be placed in a pattern to match probing contacts on the probe card 208. The die placement pattern can be adapted or chosen based on commonality of pattern for use in a plurality of subsequent test stations. For example, the die can be maintained in the same configuration pattern for high frequency, and burn-in, and final testing. The placement of the die can be chosen to facilitate certain testing situations. For example, die placement can be chosen to address reducing the effects of substrate noise or die current leakage. Die placement can take into consideration heat dissipation of die under anticipated test conditions.

FIG. 7 illustrates an exemplary process 700 that can include manufacturing, testing, and further processing of semiconductor dies according to some embodiments of the invention. As shown, process 700 can include manufacturing semiconductor dies on a wafer at 702. As is known, dies comprising circuitry integrated into a semiconductor material can be made many at a time, for example, as generally described above with respect to FIG. 1. FIG. 8 illustrates an exemplary wafer 802 with a plurality of dies 804 manufactured on the wafer 802. As is known, each die 804 can include circuitry integrated into a portion of the wafer 802, and each die 804 can include bond pads or other electrically conductive terminals that provide input and output connections to and from the circuitry. In FIG. 8, 28 dies 804 are shown on wafer 802, and each die 804 is shown with eight terminals 806 (e.g., bond pads or other types of terminals), although more or fewer dies 804 can be made on a wafer 802, and each die 804 can have more or fewer terminals 806. Moreover, the pattern of the dies 804 on wafer 802 and the pattern of the terminals 806 on the dies 804 shown in FIG. 8 are exemplary only and other patterns can be implemented.

The circuitry integrated into the dies 804 can be any type of circuitry, including without limitation any type of digital, analog, or mixed digital and analog circuitry. Non-limiting examples include memory circuits, processor circuits, controller circuits, logic circuits, amplifier circuits, etc. The wafer 802 can be made of any semiconductor material including without limitation silicon, gallium arsenide, etc. The circuitry (not shown) can be formed on each die 804 using any method for forming integrated circuitry into a semiconductor material now known or later developed. Alternatively, dies 804 can be optical devices or a combination of optical and electrical devices.

As is known, the dies 804 can eventually be singulated from the wafer 802 and can then be packaged. Alternatively, packaging for the dies 804 can be formed on the wafer 802 before the dies 804 are singulated from the wafer 802. For example, wafer level packaging (WLP) techniques can be used to form packaging on the wafer 802 prior to singulating the dies 804 from the wafer 802. Many WLP techniques are known, and any WLP technique now known or later developed can be used to form packaging for each die 804 on wafer 802.

FIGS. 9 and 10 illustrate an exemplary WLP package formed on one die 804 according to some embodiments of the invention. Elements 908 in FIGS. 9 and 10 can be the native bond pads of the die 804. For ease of illustration, only one die 804 is shown in FIGS. 9 and 10. Similar WLP packaging can, however, be formed on each of the dies 804 of wafer 802. As shown, the exemplary WLP package shown in FIGS. 9 and 10 can include redistribution traces 902 and interconnection ele-

ments 904 (e.g., packaging terminals). The redistribution traces 902 can be any electrically conductive material suitable for electrically connecting a bond pad 908 of the die 804 to an interconnection element 904. Examples of suitable materials include metals (e.g., copper, gold, etc.), conductive polymers, materials with embedded metal particles, etc. Redistribution traces 902 can be formed using any method suitable for forming such traces on a semiconductor die. For example, traces 902 can be made in the same way that metal interconnection layers that form part of the circuitry of the die 804 are made.

The interconnection elements 904 can be the means by which the circuitry of the die 804 electrically connects to another electronic device (e.g., a printed circuit board, a flex circuit, another die, etc.). Interconnection elements 904 can therefore be any elements suitable for making electrical connections with another electronic device. Examples of suitable interconnection elements 904 include solder balls, conductive bumps, conductive posts, conductive beams, conductive wires, etc. Although the exemplary interconnection elements 904 are illustrated in FIGS. 9 and 10 as semi-spheres, the interconnection elements 904 can be many other shapes.

Although not shown in FIGS. 9 and 10, WLP packaging formed on dies 804 can also include one or more additional materials. For example, a protective layer of material (e.g., a passivation layer) can be deposited over the die 804, including bond pads 908 and the redistribution traces 902. Openings (not shown) can be provided in such a protective layer for interconnection elements 904.

The WLP packaging shown in FIGS. 9 and 10 is exemplary only, and other WLP packaging can alternatively be formed on dies 804. As yet another alternative, packaging other than WLP packaging can be formed on dies 804. For example, chip scale packaging (CSP) can alternatively be applied to dies 804. As yet another alternative, no packaging need be applied to the dies 804. That is, the dies 804 can be bare and unpackaged, in which case the bond pads 908 can provide input to and output from the internal circuitry of the die 804.

As used herein, the term "terminal" refers to any electrical structure on a die that provides input into and/or output from the die 804. The term "terminal," and the depiction of terminals 806 in the drawings, thus refers to any such electrical structure including but not limited to native bond pads (e.g., bond pads 908) of the die or any interconnection element (e.g., 904) added to the die 804, for example, as part of packaging.

Regardless of the type of packaging formed on dies 804, or whether any packaging is formed on dies 804, dies 804 can include alignment marks 906 as shown in FIG. 9. As will be seen, the alignment marks 906 can be used to align the dies 804, for example, in placing singulated dies 804 onto a carrier (see 708 of FIG. 7). Although three alignment marks 906 are shown in FIG. 9, more or fewer can be used. Moreover, alignment marks 906 can take other forms and/or shapes and can be placed in different locations and/or patterns than shown in the example of FIG. 9. As yet another alternative, dies 804 need not include alignment marks, such as alignment marks 906. In yet another alternative, an optical device can use a die 804 feature or features (e.g., one or more corners of the die 804, a terminal 806, etc.) to determine an orientation of the die 804.

Referring again to FIG. 7, once manufactured at 702, the dies 804 can be tested at 704. The testing at 704 can be basic, fast tests designed to identify dies 804 with gross defects. For example, the initial basic testing at 704 can perform tests designed to determine whether a die 804 has any of the following faults: a terminal 806 or other portion of the circuitry of the die 804 is shorted to a power distribution line; a

power input terminal (e.g., one of terminals **806**) draws excessive current; or one of terminals **806** has an open circuit or a short circuit fault. Other examples of testing that can be part of the initial basic testing at **704** can include determining whether the die **804** properly responds to the application of power to the die **804**, and determining whether the die **804** responds to one of a few basic functions the circuitry of the die **804** is designed to perform. For example, if the die **804** is a memory die (e.g., the die **804** includes digital memory circuitry) or includes a memory (e.g., cache memory), one or a few basic read and write operations can be performed on the die at **704**. Such basic read and/or write operations can be designed not to test exhaustively whether the die **804** responds properly to all possible data patterns that can be written to and/or read from the die **804** but merely to determine whether a read and/or write operation can be performed on the die **804**. Alternatively, the initial basic testing at **704** can be skipped and, for example, performed later. For example, the initial basic testing at **704** can be performed at **710**.

At **706**, the dies **804** can be singulated from wafer **802**. Dies **804** can be singulated from wafer **802** in the same or similar ways as described above with respect to **108** of FIG. 1. Dies **804** that did not pass initial basic testing at **704** can be discarded. Sequentially or simultaneously, **702**, **704**, and **706** of the process **700** of FIG. 7 can be performed to produce a plurality of singulated dies **804** from a plurality of wafers **802**.

At **708**, ones of the singulated dies **804** can be placed on a test carrier. For example, dies **804** can be placed on the carrier substrate **300** of FIG. 4, the testing substrate **400** of FIGS. 4a, 4b, and 6, the testing substrate **500** of FIGS. 5a-5b in the same way that dies **402** or **504** are placed on carrier substrate **300**, testing substrate **400**, or testing substrate **500** as described above. For example, the dies **804** can be placed on carrier substrate **300** or testing substrate **400** positioned such that terminals **806** align with probes **222** or probe elements **406**. Similarly, dies **804** can be placed on testing substrate **500** such that terminals **806** align with probes **502**.

FIGS. 11-13 illustrate an example in which singulated dies **804** can be placed on a carrier **1102**. As used herein, the term "carrier" is intended to include any substrate, structure, or surface of a structure on which singulated dies **804** can be placed. The term "carrier" includes but is not limited to a testing substrate. Carrier **1102** can be any substrate, structure, or portion of a structure (e.g., a surface of a structure) suitable for supporting a plurality of the dies **804**. For example, the carrier **1102** can be the chuck **204** of the system **200** of FIG. 2. As another example, the carrier **1102** can be a substrate suitable for supporting dies **804**. For example, carrier **1102** can be a semiconductor substrate, such as a blank silicon wafer. As yet another example, the carrier **1102** can comprise an apparatus consisting of a plurality of parts. The carrier **1102** can include a flat surface on which the dies **804** can be placed.

In some embodiments, the carrier **1102** can comprise material that is the same as material comprising the wafer **802** on which dies **804** are made. For example, the carrier **1102** and the wafer **802** can comprise a semiconductor material (e.g., silicon). If the carrier **1102** comprises material that is the same as or similar to the material of wafer **802** (and thus dies **804**), the carrier **1102** and the dies **804** can have the same or similar coefficients of thermal expansion and can thus expand or contract similarly in response to temperature changes. The carrier **1102** can be other shapes than the circular shape shown in FIGS. 11 and 13. For example, the carrier **1102** can be oval, rectangular, square, etc. shaped.

In some embodiments, the carrier **1102** can comprise a backing substrate **1202** and a tacky or sticky film **1204** disposed on the backing substrate **1202** as shown in FIG. 12. The tacky or sticky film **1204** can hold the singulated dies **804** on the carrier **1102** in place so that the dies **804** do not move appreciably on carrier **1102**. Alternatively, the carrier **1102** can include other mechanisms for holding dies **804** in place, including without limitation any of the mechanisms discussed above with respect to FIGS. 1-6. For example, a vacuum, electrostatic forces, etc. can be used to hold dies **804** in place on carrier **1102**. Carrier **1102** can thus include mechanisms for creating a vacuum, electrostatic forces, etc. As another example, mechanical mechanisms (e.g., clamps) can be used to hold the dies **804** in place. As yet another example, a weight (e.g., like weight **506**) can hold dies **804** in place on carrier **1102**, which need not include sticky film **1204**. As yet another example, the force of probes (e.g., like **406** of FIG. 4b, probes **502** of FIG. 5b, or other probes disclosed herein (e.g., probes **1410** of FIGS. 14 and 15)) pressed against terminals **806** of the dies **804** can hold the dies **804** in place on carrier **1102**. Thus, carrier **1102** can but need not include sticky film **1204**. In some embodiments carrier **1102** can comprise only substrate **1202**, and in other embodiments carrier **1102** can comprise an assembly of structural elements that form the carrier **1102**.

Carrier **1102** can also include stop structures (not shown), such as stop structures **410**, **508** of FIGS. 4c-e, 5c, and 6.

As shown in FIG. 11, whether the carrier **1102** is the chuck **204** of probing system **200** (see FIG. 2), a substrate, or another structure, singulated dies **804** can be picked out of a storage container **1110** (which can be any storage container suitable for storing or obtaining semiconductor dies (e.g., singulated die source **218** of FIG. 2)) and placed on the carrier **1102** by a pick-and-place machine **1112** (e.g., a robotic mechanism) with a robotic arm **1114** (which can be a non-limiting example of the manipulation system **210** of FIG. 2). The robotic arm **1114** can pick singulated dies **804** from the storage container **1110** and place the dies **804** on the carrier **1102**. Precision positioning mechanisms can be used to place the dies **804** in precise locations on the carrier **1102**. For example, laser positioning mechanisms **1116** can be used to position precisely the dies **804** on the carrier **1102** as shown in FIG. 11. As another example, other optical systems can be used to position precisely dies **804** on the carrier **1102**.

Referring to FIGS. 2 and 11, the pick-and-place machine **1112** can be an example of the manipulation system **210** of FIG. 2 and can thus be located in a prober housing (e.g., **202**). Moreover, the pick-and-place machine **1112** can place the dies on a surface of the chuck **204**, which can thus be the carrier **1102**. Alternatively, the pick-and-place machine **1112** can place the dies **804** on a substrate or other structure that is the carrier **1102**, and in such a case, the pick-and-place machine **1112** can also place the carrier **1102** on the chuck **204** (either before placing dies **804** on the carrier **1102** or after placing dies **804** on the carrier **1102**). Once the dies **804** are on the carrier **1102** and the carrier **1102** is on the chuck **204**, or alternatively, once the dies **804** are on the chuck **204** (if the chuck **204** is the carrier **1102**), the chuck **204** can be moved to bring terminals **806** of the dies **804** into contact with probes **222** of the probe card assembly **208**, and the tester **214** can then provide test signals through the connection **216**, test head **212**, probe card assembly **208**, and probes **222** to the dies **804**. Response signals generated by the dies **804** in response to the test signals can be sensed by ones of the probes **222** and provided to the tester **214** through the probe card assembly **208**, test head **212**, and connection **216**. The tester **214** can then analyze the response signals to determine whether the

response signals is as expected and thus whether a particular die **804** passes or fails the testing.

As shown in FIGS. **11** and **13**, the carrier **1102** can include alignment marks **1104**, which can be used to position precisely the dies **804** on the carrier **1102**. Alternatively, or additionally (as shown in FIG. **11**), a first die **1150** (which can be one of the dies **804** singulated from wafer **802**) can be placed on the carrier **1102**, and a second die **1152** (which can be another one of the dies **804** singulated from wafer **802**) placed on the carrier **1102** can be aligned with the first die **1150**. Each subsequent die (e.g., dies **1154**, **1156**, **1158**) placed on the carrier **1102** can be aligned with one or more of the previously placed dies. As discussed above, dies **804** can include alignment marks **906**, which can be used to align dies **804** one with another and/or with alignment marks or features (e.g., **1104**) on the carrier **1102**. Alternatively or additionally, a feature (e.g., one or more corners of a die terminal **806**) of the dies **804** can be used as an alignment feature.

Although FIG. **13** shows the dies **804** placed on carrier **1102** in a pattern comprising three rows **1302** and four columns **1304** with horizontal spacing  $S_H$  between each column **1304** and vertical spacing  $S_V$  between each row **1302**, the dies **804** can be disposed on carrier **1102** in many different patterns. For example, the dies **804** can be placed on the carrier **1102** in a pattern that is suitable for the particular testing that is to be performed on the dies **804**. As another example, the dies **804** can be placed on the carrier **1102** in a pattern that includes a number of dies **804** such that the total number of die terminals **806** in the pattern is as close as possible to the number of connections to and from a tester (e.g., any device configured to control testing of the dies) that will be used to test the dies **804**. As yet another example, the dies **804** can be disposed in a pattern that facilitates dissipating heat from the dies **804** during the testing. As still another example, the dies **804** can be disposed in a pattern that reduces cross talk or other forms of electrical interference between signal probes carrying signals to or from the dies **804** during testing of the dies **804**.

Although the forgoing examples of particular patterns in which the dies **804** can advantageously be placed on the carrier **1102** are applicable to the use of many different types and configurations of contactor devices with probes for contacting the dies **804** during testing of the dies **804**, the exemplary patterns mentioned above will be discussed in more detail with respect to the exemplary contactor device shown in FIGS. **14** and **15**. Initially, however, the exemplary contactor device shown in FIGS. **14** and **15** will be described.

As shown in FIG. **14** (which shows a bottom, perspective view of the probe card assembly **1402**) and FIG. **15** (which shows a side view of the probe card assembly **1402** connected by communications channels **1504** to a tester **1502**), probe card assembly **1402**, which can be a non-limiting example of the probe card assembly **208** shown in FIG. **2** (and can thus be used in a probing system like system **200** of FIG. **2**), can include a wiring substrate **1404**, a flexible electrical connector **1514**, and a probe substrate **1408**. The wiring substrate **1404** can comprise any substrate suitable for supporting electrical connectors **1506**, which can electrically connect the probe card assembly **1402** to communications channels **1504** to and from a tester **1502** (e.g., a source of test signals). The wiring substrate **1404** can also include a plurality of electrically conductive paths (not shown) from the electrical connectors **1506** to the flexible electrical connector **1514**. The conductive paths (not shown) can be in the form of electrically conductive traces (not shown) and/or vias (not shown) on, in, and or through the wiring substrate **1404**.

The probe substrate **1408** can comprise any substrate suitable for supporting the probes **1410**. The probe substrate **1408** can also include a plurality of electrically conductive paths (not shown) from the probes **1410** to the flexible electrical connector **1514**. The conductive paths (not shown) through the probe substrate **1408** can be in the form of electrically conductive traces (not shown) and/or vias (not shown) on, in, and or through the probe substrate **1408**.

The flexible electrical connector **1514** can provide a plurality of electrically conductive paths (not shown) from the wiring substrate **1404** to the probe substrate **1408**. The flexible electrical connector **1514** can comprise any type of electrical connections that are sufficiently flexible (or compliant) to maintain electrical connections between the wiring substrate **1404** and the probe substrate **1408** even if the probe substrate **1408** is moved relative to wiring substrate **1404**. Although not shown, the probe card assembly **1402** can comprise a mechanism for moving (e.g., rotating, tilting, translating, etc.) the probe substrate **1408** with respect to the wiring substrate **1404**. Examples of such mechanisms are disclosed in U.S. Pat. Nos. 5,974,662; 6,509,751; and U.S. patent application Ser. No. 11/306,515, filed Dec. 30, 2005. For example, electrical connector **1514** can comprise flexible wires. As another example, electrical connector **1514** can comprise an interposer (e.g., like the interposer **504** disclosed in FIG. 5 of U.S. Pat. No. 5,974,622). A mechanical stiffener (e.g., a metal plate) can be attached to the wiring substrate **1404** to provide mechanical stiffness. Alternatively, a mounting structure (not shown) can be provided for mounting the probe card assembly **1402** to a housing of a test system (e.g., like prober **202** of FIG. **2**), and the probe substrate **1408** can be alternatively or additionally moveable with respect to the mounting structure.

The electrical connectors **1506**, conductive paths (not shown) through the wiring substrate **1404**, the flexible electrical connector **1514**, and the probe substrate **1408** can provide individual electrical connections between ones of the channels **1504** and ones of the probes **1410**, Brackets **1406** and/or other attachment mechanisms (e.g., clamps, bolts, screws, etc.) can hold the probe substrate **1408**, flexible electrical connector **1514**, and wiring substrate **1404** together.

The electrical connectors **1506** can comprise any mechanism for providing electrical connections to the communications channels **1504**. For example, the electrical connectors **1506** can comprise zero-insertion-force (“ZIF”) electrical connectors configured to receive mating ZIF connectors (not shown) at the end of the communications channels **1504**. As another non-limiting example, electrical connectors **1506** can comprise pogo pin pads configured to receive pogo pin electrical connectors at the end of communications channels **1504**.

The probes **1410** can be resilient, conductive structures. Non-limiting examples of suitable probes **1410** include composite structures formed of a core wire bonded to a conductive terminal (not shown) on the probe substrate **1408**, and the core wire can be over coated with a resilient material as described in U.S. Pat. Nos. 5,476,211, 5,917,707, and 6,336,269. Probes **1410** can alternatively be lithographically formed structures, such as the spring elements disclosed in U.S. Pat. Nos. 5,994,152, 6,033,935, 6,255,126, 6,945,827, U.S. Patent Application Publication No. 2001/0044225, and U.S. Patent Application Publication No. 2004/0016119. Still other non-limiting examples of probes **1410** are disclosed in U.S. Pat. Nos. 6,827,584, 6,640,432, 6,441,315, and U.S. Patent Application Publication No. 2001/0012739. Other non-limiting examples of probes **1410** include electrically conductive pogo pins, bumps, studs, stamped springs, needles, buckling beams, etc.

The probe substrate **1408** is exemplary only. In some embodiments, the probe substrate **1408** can be replaced with a probe head assembly that comprises a plurality of probe substrates (not shown) to which the probes **1410** are attached, and those probe substrates can be attached to a larger substrate (not shown) or otherwise attached to each other. Each such probe substrate can be independently moveable with respect to the larger substrate. Examples of multiple substrate probe head assemblies are disclosed in U.S. patent application Ser. No. 11/165,833, filed Jun. 24, 2005 and U.S. patent application Ser. No. 11/306,515, filed Dec. 30, 2005.

The test system of FIG. **15** can operate as follows. Tester **1502** can generate test signals to be input through ones of probes **1410** into the dies (e.g., die **804**). Tester **1502** can also evaluate response signals generated by the dies (e.g., die **804**) in response to the test signals. Tester **1502** can comprise equipment such as one or more computers. The communications channels **1504** can be a plurality of electrical paths to and from the tester **1502**. Any mechanism or medium can be used to provide the communications channels **1504**. For example, communications channels **1504** can comprise coaxial cables, fiber optics, wireless transmitters and receivers, twisted pairs, electric circuits, driver circuits, receiving circuits, etc. Moreover, each of channels **1504** can comprise multiple medias. For example, ones of channels **1504** can comprise a driver circuit that drives a signal down a coaxial cable to a routing circuit on one or more circuit boards, which in turn provides the signal to an electrical connector that can be connected to the electrical connectors **1506** on the probe card assembly **1402**.

As mentioned, in one example of the pattern of dies **804** on carrier **1102** (see FIGS. **11-13**), dies **804** can be placed in a pattern such that the terminals **806** of the dies **804** align with probes of a contactor device configured to contact the terminals **806** of the dies **804**. For example, as discussed above, probe card assembly **1402** can be an example of a contactor device for contacting dies **804** on carrier **1102**. In such a case, dies **804** can be positioned on carrier **1102** such that the terminals **806** of the dies **804** align with the probes **1410** of the probe card assembly **1402**. Although the probes **1410** of probe card assembly **1402** are shown in FIG. **14** disposed on a probe substrate **1408** in a rectangular or square array with similar spacing between each probe **1410**, probes **1410** can be disposed in many different patterns. Regardless of the particular pattern of probes **1410**, dies **804** can be placed on carrier **1102** (e.g., as shown in FIG. **13**) such that the terminals **806** of the dies **804** align with the probes **1410**.

As also mentioned above, another example of a pattern in which dies **804** can be placed on carrier **1102** correlates the number of terminals **806** of the dies **804** placed on the carrier **1102** with the number of resources available from the tester that will be used to test the dies **804**. For example, the number of dies **804** placed on the carrier **1102** can correspond to a number of connections to and from a tester (e.g., like tester **214** of FIG. **2** or tester **1502** of FIG. **15**) that will be used to test the dies **804**. In one example, the total number of dies **804** placed on the carrier **1102** can be selected to make maximum usage of the available tester resources. Referring to FIG. **15**, as discussed above, communications channels **1504** can comprise a plurality of individual communications channels (or paths) to and/or from the tester **1502**. With regard to tester **1502**, a number  $N$  of dies **804** placed on the carrier **1102** can be such that the number  $N$  multiplied by the number  $M$  of terminals **806** on each die are as close to the number  $C$  of communications channels **1506** as possible. In some embodiments, the probe card assembly **1402** can include wiring that fans some of the communications channels **1504** to multiple

probes **1410**. In such a case, there can be more probes **1410** than communications channels **1504** (some communications channels **1504** being electrically connected through the probe card assembly **1402** to more than one probe **1410**). In such a case, the number  $N$  of dies **804** placed on the carrier **1102** can be such that the number  $N$  multiplied by the number  $M$  of terminals **806** on each die are as close as possible to the number  $P$  of probes **1410** connected to a communications channel **1504**.

In other examples, the number  $N$  of dies **804** placed on the carrier **1102** can be such that the number  $N$  of dies **804** multiplied by the number  $M$  of terminals **806** on each die are as close to an integer multiple  $I$  of the number  $C$  of communications **1504** and/or the number  $P$  of probes **1410** connected to a communications channel **1504**. In such a case, the probes **1410** can be brought into contact with a first set of the dies **804**, and the first set of the dies **804** can be tested. Carrier **1102** can then be repositioned such that a second set of dies **804** on the carrier **1102** are brought into contact with the probes **1410**, and the second set of dies **804** tested. The foregoing process of contacting and testing a set of the dies **804**, testing the set of dies **804**, and then repositioning the carrier **1102** to contact and test another set of dies **804** can be repeated until all of the dies **804** on the carrier **1102** are contacted and tested, which can require  $I$  number of different touchdowns of probes on the dies **804**.

As mentioned above, dies **804** can be placed in a pattern that includes sufficient spacing (e.g., vertical spacing  $S_V$  and horizontal spacing  $S_H$  shown in FIGS. **11** and **13**) between dies **804** to allow the dies to dissipate enough heat during testing of the dies **804** to maintain the dies **804** within the manufacturer's specified operating temperature range for the dies **804**. What constitutes sufficient spacing to dissipate heat can vary depending on a number of parameters including without limitation the type of die, the number of dies being tested simultaneously, the manufacturer's specified operating temperature range, etc. For example, the particular spacings (e.g.,  $S_H$ ,  $S_V$ ) between dies **804** can depend on the wattage generated by the dies **804** during operation and the number of dies **804** placed on the carrier **1102**.

The following is another example of a placement pattern for the dies **804** that can facilitate dissipation of heat. The carrier **1102** can be capable of dissipating heat generated by dies **804** at a rate of a particular number  $W$  of watts per unit area of the carrier **1102**. That number  $W$  of watts can depend on the material or materials that the carrier **1102** is made of and can further depend on the particular construction of the carrier. The number  $W$  for a particular carrier **1102** can be determined by experiment. The particular spacing (e.g.,  $S_H$ ,  $S_V$ ) between dies **804** can be selected so that the number  $D$  of dies **804** multiplied by the power rating  $P$  (e.g., the manufacturer's specification of the number of watts generated by a die **804** during operation of the die) of each die **804** is less than or equal to the total number of watts the carrier **1102** is able to dissipate. In other words, the particular spacing (e.g.,  $S_H$ ,  $S_V$ ) or simply the number  $D$  of dies **804** placed on the carrier can be as follows:  $D * P \leq W * A$  (where  $D$  is the number of dies **804** placed on the carrier **1102**;  $P$  is the power output or consumed or the heat output during operation of a die **804** or power output rating assigned to the dies **804** by the manufacturer of the dies **804**;  $W$  is the number of watts per unit of surface area that the carrier **1102** is able to dissipate;  $A$  is the area of the surface of the carrier **1102** on which the dies **804** are placed;  $*$  represents multiplication; and  $\leq$  represents less than or equal).

As also mentioned above, in yet another example of the pattern in which dies **804** can be placed on the carrier **1102**,



the dies **804** can be placed with sufficient spacing to reduce cross talk or other forms of electrical interference between the dies **804** as multiple dies **804** are tested simultaneously on carrier **1102**. Again, what constitutes sufficient spacing to reduce cross talk or other forms of electrical interference can vary depending on a number of parameters including without limitation the type of the dies, the type of signals input into and output from the dies, the frequency at which signals are input into and output from the dies, etc. For example, the particular spacings (e.g.,  $S_H$ ,  $S_V$ ) between dies **804** can be selected to reduce cross talk and other forms of electrical interference between the dies **804** on the carrier **1102** to a level that is negligible (e.g., does not interfere with testing the dies **804** at typical operating frequencies of the dies **804**).

As another example, the particular spacings (e.g.,  $S_H$ ,  $S_V$ ) between dies **804** can be selected to reduce cross talk and other forms of electrical interference between signal probes (e.g., like ones of probes **222** of FIG. 2, ones of probe elements **406** of FIG. 4*b*, ones of probe elements **502** of FIG. 5*a*, or ones of probes **1410** of FIGS. 14 and 15) of a contactor device (e.g., like probe card assembly **208** of FIG. 2, intermediate connection device **404** of FIG. 4*c*, testing substrate **500** of FIG. 5*a*, and probe card assembly **1402** of FIGS. 14 and 15). In some embodiments, at test frequencies of about 100 megahertz or greater, cross talk and/or other forms of electrical interference between such signal probes can be reduced to negligible levels if the average density of probes is two or fewer per square millimeter of the surface of the substrate to which the probes are attached. For example, if the average density of signal probes **1410** (probes configured to carry test signals to or response signals from the die **804**) on the bottom surface of probe substrate **1408** is less than two probes per square millimeter of surface area of the probe substrate **1408**, cross talk and other forms of electrical interference can typically be reduced to negligible levels even if the test and/or response signals are switched at frequencies of 100 megahertz or greater. Because the signal probes **1410** contact ones of the signal terminals **806** of the dies **804**, by properly spacing (e.g.,  $S_H$ ,  $S_V$ ) the dies **804** on the carrier **1102**, the density of signal probes **1410** can be kept to two or fewer per square millimeter of the surface of the probe substrate **1408**.

In some embodiments, the carrier (e.g., like carrier **1102**) can include circuit elements and other circuitry that can be used in testing the dies. FIGS. 16 and 17 illustrate an exemplary carrier **1602** that can include power distribution lines **1604** and ground lines **1606** according to some embodiments of the invention. The carrier **1602** can also include decoupling capacitors **1608**, which can be electrically connected between a power distribution line **1604** and a ground line **1606** as shown in FIGS. 16 and 17. Other electronic components (e.g., resistors) can also be included on carrier **1602**. Carrier **1602**, like carrier **1102**, can take shapes other than circular, including without limitation oval, rectangular, square, etc.

As shown in FIGS. 16 and 17, carrier **1602** can also include a plurality of test sites **1610**, each of which can include a die site **1650** where a die **804** to be tested can be located and circuitry **1620** (e.g., application circuitry) that can be used to test one or more of the dies **804**. In FIGS. 16 and 17, there is a die **804** disposed in each die site **1650**. Circuitry **1620** can be, for example, circuitry that functions like one or more electronic devices that a die **804** is designed to operate with in an electronics system. For example, if die **804** is a memory die, the circuitry **1620** can be processor circuitry that writes data to and reads data from the memory die. Circuitry **1620** can thus mimic operation of a processor die that the memory

die (**804**) will operate with in an electronics system. Alternatively, circuitry **1620** can be a processor die. Indeed, circuitry **1620** can comprise one or more dies that a die **804** is designed to operate with in an electronics system.

As shown in FIG. 16, each test site **1610** can also include control inputs **1624** by which the circuitry **1620** can be controlled, and outputs **1622** from the circuitry **1620**, which can be provided to a die **804**. A contactor device (e.g., the probe card assembly **208** of FIG. 2, the intermediate connection device **404** of FIG. 4*c*, the testing substrate **500**, or the probe card assembly **1402** of FIGS. 14 and 15) can be configured to contact the control inputs **1624** and thereby control the circuitry **1620**, causing circuitry **1620** to generate outputs that are provided through outputs **1622** to a die **804**. The contactor device (not shown) can also be configured to contact terminals **806** and thereby monitor signals generated by the die **804**. A tester (e.g., like tester **214** of FIG. 2 or tester **1502** of FIG. 15) can provide the control signals to the circuitry **1620** and can receive and analyze the response signals generated by the die **804**. In this way, each die **804** can be tested as part of a system that the die **804** is designed to operate in.

In some embodiments, the outputs **1622** can be configured to be selectively connectable to the dies **804** so that the dies **804** can be selectively tested with circuitry **1620** or selectively tested without circuitry **1620**. The contactor device (e.g., the probe card assembly **208** of FIG. 2, the intermediate connection device **404** of FIG. 4*c*, the testing substrate **500**, or the probe card assembly **1402** of FIGS. 14 and 15) can be configured to control whether the circuitry **1620** is activated and its outputs **1622** connected to dies **804** or whether dies **804** are tested by themselves. Alternatively, one contactor device can be configured to contact the control inputs **1624** to the circuitry **1620** and connect the outputs **1622** of the circuitry **1620** to the dies **804** and thereby test dies **804** with circuitry **1620**, and a second contactor device can be configured to contact only the dies **804** and thereby test the dies **804** without circuitry **1620**.

A non-limiting, exemplary configuration of a test site **1610** is shown in FIG. 16*b*. As shown, control inputs **1624** can comprise electrically conductive pads **1784** and electrically conductive traces **1782** can be provided from the pads **1784** to circuitry **1620**. Outputs **1622** can comprise electrically conductive traces **1708** that terminate in pads **1710**, which can be located generally close to the die site **1650** as shown. In the example shown in FIG. 16*b*, the terminals **806** of the die **804** can be configured as follows: terminals **1720** can be input terminals through which signals can be input into the circuitry of the die **804**; terminals **1724** can be output terminals through which the circuitry of the die **804** can output signals; terminal **1722** can be a power terminal through which power can be provided to the circuitry of the die **804**; and terminal **1726** can be a ground terminal through which a ground connection can be provided to the circuitry of the die **804**. The foregoing configuration of the terminals **806** of die **804** is exemplary only and for purposes of illustration, discussion, and example. Many other numbers and configurations of terminals **806** can be provided for a die **804**.

FIG. 17*a* illustrates a partial view of a portion of a contactor device **1750** (e.g., a first contactor device) with exemplary probes for contacting pads and terminals of a test site **1610** of FIGS. 16*a* and 16*b*. Additional such probes can be provided for contacting pads of all or additional ones of the test sites **1610** and all or additional ones of the terminals **806** of the dies **804** on the carrier **1602**. The contactor device **1750** shown in partial view in FIG. 17*a* can be like the probe card assembly **208** of FIG. 2, the intermediate connection device **404** of FIG. 4*c*, the testing substrate **500**, or the probe card assembly **1402**

of FIGS. 14 and 15. For example, the substrate 1752 can be like the probe substrate 1408 of FIGS. 14 and 15. As shown in FIG. 17a, the contactor device 1750 can include a plurality of probes (e.g., a first plurality of probes) (which can be like probes 222 of FIG. 2 or probes 1410 of FIGS. 14 and 15), only a few of which are shown in FIG. 17a. Probes 1754 (e.g., a first set of the probes) can be located to contact pads 1784 of FIG. 16b, and probes 1774 (a second set of the probes) can be configured to contact output terminals 1724, which can be ones of the terminals 806 of the die 804 shown in FIG. 16b configured to output signals from the die 804.

As also shown in FIG. 17a, the contactor device 1750 can also include electrically connected pairs 1756 of probes (e.g., a third set of probes), each comprising two probes 1756, 1762 electrically connected by a trace 1760. One probe (e.g., 1756) in each probe pair 1756 can contact one of the pads 1710, and the other probe (e.g., 1762) can contact one of input terminals 1720 (which, as discussed above, can be ones of the terminals 806 of the die 804 configured to be input terminals, as shown in FIG. 16b). Each probe pair 1756 can thus electrically connect one of the pads 1710—and thus one of the outputs from the circuitry 1620—to an input terminal 1720 of the die 804. As shown, the contactor device 1750 can also include probe pairs 1764 and 1776. Probe pair 1764 can include two probes 1768 and 1772 electrically connected by a trace 1770, and probe pair 1776 can similarly include two probes 1778 and 1782 electrically connected by a trace 1780. Probe 1768 can be brought into contact with power line 1604, and probe 1772 can be brought into contact with power input terminal 1722, which can be one of the terminals 806 of the die 804 configured to receive power for the die 804. An electrical connection from power line 1604 to power input terminal 1722 can thus be provided. Similarly, probe 1782 can be brought into contact with ground line 1606, and probe 1778 can be brought into contact with ground input terminal 1726, which can be one of the terminals 806 of the die 804 configured to receive a ground connection. An electrical connection from ground line 1606 to ground input terminal 1726 can thus be provided.

If contactor device 1750 is configured like probe card assembly 1402 of FIGS. 14 and 15 and connected to a tester like tester 1502 through communications channels like communications channels 1504 of FIG. 15, the tester 1502 can provide control signals (e.g., which can be termed “test signals”) through probes 1754 to pads 1784 and traces 1782 to circuitry 1620. The tester 1502 can thus control the circuitry 1620. Output signals (e.g., application circuit output signals) generated by the circuitry 1620 can be provided through traces 1708, pads 1710, and probe pairs 1756 to input terminals 1720 of the die 804. Response signals (e.g., die output signals) generated by the die 804 in response to the signals output by the circuitry 1620 can be sensed by the probes 1774 in contact with output terminals 1724 and provided through the contactor device 1750 and communications channels 1504 to the tester 1502. The tester 1502 can then analyze the response signals to determine whether the response signals are as expected and thus whether the die 804 passes the testing. The tester 1502 can thus test die 804 by causing the circuitry 1620 to generate input signals for die 804 that drive the die 804 and then monitoring the response of the die 804 to the signals from circuitry 1620.

FIG. 17b shows a partial view of another contactor device 1751 (e.g., a second contactor device), which can be generally similar to contactor device 1750 except for the configuration of probes on substrate 1753 (which can be like substrate 1752). As shown, contact device 1751 can include probes 1784 configured to contact the input terminals 1720 of die

804, probes 1788 configured to contact the output terminals 1724 of die 804, and power and ground probes 1786, 1790 configured to contact power and ground terminals 1722, 1726 of die 804. If contactor device 1751 is configured like probe card assembly 1402 of FIGS. 14 and 15 and connected to a tester like tester 1502 through communications channels like communications channels 1504 of FIG. 15, the tester 1502 can provide test signals through probes 1784 directly to input terminals 1720 of the die 804. Response signals generated by the die 804 in response to the test signals can be sensed by the probes 1788 and provided through the contactor device 1751 and communications channels 1504 to the tester 1502. The tester 1502 can then analyze the response signals to determine whether the response signals are as expected and thus whether the die 804 passes the testing. Power and ground connections can be provided to the die 804 from tester 1502 through probes 1786 and 1790 to power and ground terminals 1722 and 1726 of the die 804. The tester 1502 can thus test die 804 by providing signals (e.g., which can be termed test signals) directly to the die 804 and monitoring the response of the die 804 to the signals. Contactor device 1751 can include additional probes for contacting all of the dies 804 on carrier 1602.

Utilizing the carrier 1602 of FIGS. 16 and 17, dies 804 can be tested in conjunction with circuitry 1620 simply by utilizing a contactor device 1750 configured as shown in FIG. 17a. Alternatively, dies 804 can be tested without circuitry 1620 simply by utilizing a contactor device 1751 configured as shown in FIG. 17b. Indeed, multiple tests can be run on the dies 804 utilizing a carrier like carrier 1602. For example, initial tests testing the basic functionality of dies 804 by themselves can be run by utilizing the probes 1784, 1786, 1788, 1790 of the contactor device 1751 (e.g., by bringing the contactor device 1751 into contact with the terminals 1720, 1722, 1724, 1726 of dies 804 and providing test signals from a tester, like tester 1502, to the dies 804 and monitoring and analyzing response signals generated by the dies 804). Thereafter, additional testing can be performed on the dies 804 utilizing circuitry 1620 (e.g., by bringing the contactor device 1750 into contact with the pads 1724, pads 1710, power line 1604, ground line 1606, and terminals 1720, 1722, 1724, 1726 of dies 804 and testing the dies 804 with the use of circuitry 1620 as discussed above).

Alternatively, initial testing can be performed with contactor device 1750 and further testing with contactor device 1751. Moreover, the configurations of power lines 1604, ground lines 1606, pads 1724, 1710, traces 1722, 1708, the number of terminals 806 and the signals assigned to each terminal 806 and the corresponding number and assignment of signals to probes 1754, 1758, 1762, 1768, 1772, 1774, 1778, 1782 can be other than shown in the examples illustrated in FIGS. 16a-17b. Also, the probes 1754, 1758, 1762, 1768, 1772, 1774, 1778, 1782 can be like probes 222 of FIG. 2 probes 406 of FIG. 4c, probes 502 of FIG. 5b, or probes 1410 of FIGS. 14 and 15. In addition, contactor device 1750 can be modified to provide power and ground to dies 804 in the same way that contactor device 1751 provides power and ground to dies 804—through probes like probes 1786, 1790. Similarly, contactor device 1751 can be modified to provide power and ground to dies 804 in the same way that contactor device 1750 provides power and ground to dies 804—be creating a connection from power line 1602 and ground line 1606 to power and ground terminals of the dies 804.

The configuration of carrier 1602 illustrated in FIGS. 16a and 16b and the configuration of contactor devices 1750 and 1751 illustrated in FIGS. 17a and 17b are exemplary only and many variations are possible. For example, dies 804 can be configured to receive inputs from a tester (e.g., tester 1502)

and provide outputs to application circuitry 1620, which can then be provided to the tester for evaluation. Thus, for example, outputs 1622 can comprise outputs from die 804 to application circuitry 1620, and control inputs 1624 can be replaced with outputs that can be contacted by probes of a contactor device that is in turn connected to the tester. As yet another exemplary modification, application circuitry 1620 can be connectable to more than one die 804. As yet another example, one die 804 can be connectable to multiple circuitries, each generally like application circuitry 1620 but each configured to perform different functions and/or simulate different circuits the dies 804 are designed to be used with in a final application.

FIGS. 18-21 illustrate an exemplary carrier apparatus according to some embodiments of the invention. As shown in FIGS. 18 and 19, the carrier apparatus can include a base 1800, which can include a cavity 1806 for receiving a carrier substrate 2002 (see FIG. 20). The base can include a sealing gasket 1804 around the cavity 1806. The base can also include threaded holes 1808, 1810. Cavity 1806 can take shapes other than circular, including without limitation oval, rectangular, square, etc. Alternatively, the carrier 2002 can be a surface of the base 1800 (e.g., a surface of the cavity 1806).

As shown in FIG. 20, dies 804 can be disposed on a carrier substrate 2002, which can be like any of carrier substrate 300, testing substrate 400, testing substrate 500, carrier 1102, or carrier 1602. Dies 804 can be placed on carrier substrate 2002 in any manner described above with respect to the foregoing carrier substrates, testing substrates, or carriers (300, 400, 500, 1102, 1602). As also shown in FIG. 20, an intermediate connection device 2000 (e.g., a first interface device) can be attached to the base 1800. For example, the intermediate connection device 2000 can be bolted, screwed, clamped, or otherwise attached to the base 1800. In one non-limiting example, bolts (not shown) can pass through holes (not shown) in a flange 2006 of the intermediate connection device 2000 and thread into threaded holes 1808 in the base 1800 (see FIG. 18). As shown in FIG. 20, the flange 2006 of the intermediate connection device 2000 can thus be tightened against the gasket 1804 and thereby form a hermetically sealed mechanical engagement with the base 1800. The intermediate connection device 2000 can be made of a material or material that is generally solid (e.g., metal, printed circuit board material, ceramic, plastic, etc.), and the base 1800 can be generally similar so that while the intermediate connection device 2000 is attached to the base 1800, the base 1800 and the intermediate connection device 2000 form a hermetically sealed enclosure space that includes the cavity 1806 in which the carrier substrate 2002 with dies 804 is located. The cavity 1806 can thus provide a hermetically sealed, clean space for dies 804. As is known, semiconductor dies, such as dies 804, are typically manufactured in a clean room environment. Dies 804, while still in a clean room environment, can be placed in cavity 1806 and intermediate connection device 2000 attached to the base 1800 as described above. Because the intermediate connection device 2000 and the base 1800 can form a sealed enclosure that includes the cavity 1806 as described above, the base 1800 and intermediate connection device 2000 can then be removed from the clean room environment without exposing the dies 804 to contaminants. The cavity 1806 can thus provide a clean room space for the dies 804 as the dies 804 are tested, transported, etc.

As shown in FIG. 20, the intermediate connection device 2000 (which can be a non-limiting example of the intermediate connection device 404 of FIG. 6) can include an interface portion 2004 that provides electrically conductive paths 2010 (e.g., electrically conductive traces and/or vias), which

can be electrical connections, between electrically conductive terminals 2008 (e.g., a first electrical interface) on an outer surface of the intermediate connection device 2000 and probes 2012 disposed to contact terminals 806 of the dies 804 as shown in FIG. 20. The interface portion 2004 of the intermediate connection device 2000 can thus provide an electrical interface, in the form of terminals 2008, to die terminals 806.

The probes 1012 can be configured to be pressed against the die terminals 806, and the force of the probes 2012 against the die terminals 806 can hold the dies in place on the carrier substrate 2002. Alternatively or additionally, means can be provided to hold the dies 804 in place on the carrier substrate, including any of the means discussed above (e.g., a vacuum, electrostatic charges, an adhesive, a sticky or tacky film (e.g., like 1204 of FIG. 12)). Probes 2012 can be like any of the probes or probe elements discussed herein, including without limitation probes 1410 of FIGS. 14 and 15.

As shown in FIG. 21, a tester interface device 2100 (e.g., a second interface device) can also be attached to the base 1800. For example, the tester interface device 2100 can be bolted, screwed, clamped, or otherwise attached to the base 1800. In one non-limiting example, bolts 2114 can pass through holes (not shown) in a flange 2106 of the tester interface device 2100 and thread into threaded holes 1810 in the base 1800 (see FIG. 18).

As shown in FIG. 21, the tester interface device 2100 (which can be a non-limiting example of the top 606 of FIG. 6) can include an interface portion 2104 that provides electrically conductive paths 2110 (e.g., electrically conductive traces and/or vias) between electrically conductive terminals 2108 (e.g., a second electrical interface) on an outer surface of the tester interface device 2100 and electrical connectors 2112 (e.g., first electrical connectors) disposed to contact terminals 2008 of the intermediate connection device 2000 as shown in FIG. 21. Electrical connectors 2112 can be any suitable mechanism for making electrical connections with the terminals 2008 of the intermediate connection device 2000. Non-limiting examples of suitable electrical connectors 2112 include pogo pin connectors, zero-insertion-force electrical connectors, resilient spring contacts, etc. The interface portion 2104 of the tester interface device 2100 can thus provide an electrical interface, in the form of terminals 2108, to a tester (e.g., like tester 214 of FIG. 2 or tester 1502 of FIG. 15).

The apparatus shown in FIG. 21 can thus provide electrical connections between electrically conductive terminals 2108 on an outside surface of the tester interface device 2100 and probes 2012 in contact with terminals 806 of the dies (see also FIG. 20). A tester (e.g., tester 214 of FIG. 2 or tester 1502 of FIG. 15) can be connected to the terminals 2108 on the outside surface of the tester interface device 2100 and thereby form a plurality of electrical connections to and from the dies 804. The tester can then generate test signals that are input into the dies 804, and the tester can monitor (e.g., sense through ones of the probes 2012) response signals generated by the dies 804 in response to the test signals. The tester can then analyze the response signals to determine whether the response signals generated by a particular die 804 are as expected and therefore whether the die passes the testing. The number, locations, and signal assignments of the terminals 2108 on the outer surface of the tester interface device 2100 can be configured to interface with a particular tester. The tester interface device 2100 can be removed and replaced with a different tester interface device, which can be similar to tester interface device 2100 except that the number, locations,

and/or signal assignments of the terminals **2108** can be different and configured to interface with a different tester.

The apparatus shown in FIG. **21** can be used in many different test systems, and terminals **2108** can be configured to interface with many different testers and/or intermediate devices between such testers. For example, the apparatus shown in FIG. **21** can be placed on a chuck, like chuck **204**, in a probing system **200**, like probing system **200**. Terminals **2108** can be brought into contact with probes **222** of the probe card assembly **208**.

FIGS. **22-24** illustrate a non-limiting example in which intermediate connection device **2000** is attached to base **1800** (e.g., as shown in FIG. **20**). In FIG. **22**, a first tester interface device **2100** can be attached to the base **1800** (as described above), and the first tester interface device **2100** (e.g., a first electrical interface) can be configured to interface with communications channels **2204** from a first tester—tester **1** (**2202**) (e.g., a first source of test signals), which can be configured to run certain tests (e.g., a first set of tests). As shown in FIG. **23**, the first tester interface device **2100** can be removed and replaced with a second tester interface device **2100'** (e.g., a second electrical interface), which can be configured to interface with communications channels **2304** from a second tester—tester **2** (**2302**) (e.g., a second source of test signals). Tester **2** (**2302**) can be configured to run certain tests (e.g., a second set of tests) that can be different than the tests run by the first tester **2202**. As shown in FIG. **24**, the second tester interface device **2100'** can be removed and replaced with a third tester interface device **2100''** (e.g., a third electrical interface), which can be configured to interface with communications channels **2404** from a third tester—tester **3** (**2402**) (e.g., a third source of test signals). Tester **3** (**2402**) can be configured to run certain tests (e.g., a third set of tests) that can be different than the tests run by the first tester **2202** and the second tester **2302**. Each of the first, second, and third sets of tests can generally comprise providing test signals to the dies **804**, sensing response signals generated by the dies **804**, and analyzing the response signals to determine if the response signals are as expected and thus whether the dies pass the testing.

Each tester **2202**, **2302**, **2402** in FIGS. **22**, **23**, and **24** can be configured like and function generally like tester **214** of FIG. **2** or tester **1502** of FIG. **15**, yet each tester **2202**, **2302**, and **2402** can be different one from another. For example, each tester **2202**, **2302**, **2402** can be configured to output different numbers, types, sequences, etc. of test signals to dies **804** (located within a cavity in base **1800** (see FIG. **20**)). Each tester **2202**, **2302**, **2402** can also be configured to monitor different outputs from the dies **804**. Although each set of communications channels **2204**, **2304**, **2404** can be generally similar to communications channels **1502** of FIG. **15**, each set of communications channels **2204**, **2304**, **2404** can be different one from another. For example each set of communications channels **2204**, **2304**, **2404** can be configured for the particular interface or configuration of its respective tester **2202**, **2302**, **2402**, and each tester interface device **2100**, **2100'**, **2100''** can be configured to interface with one of the sets of communications channels **2204**, **2304**, **2404** as shown in FIGS. **22-24**. The number, locations, signal assignments, etc. of the terminals **2108** (see FIG. **21**) on each tester interface device **2100**, **2100'**, **2100''** can thus be different and configured specifically to interface with one of the sets of communications channels **2204**, **2304**, **2404**. The electrical connectors **2112** (see FIG. **21**), in contrast, can be positioned generally in the same locations in each tester interface device **2100**, **2100'**, **2100''** so that each tester interface device **2100**, **2100'**, **2100''** can connect to the same intermediate connection

device **2000**. Paths **2100** in each tester interface device **2100**, **2100'**, **2100''** can be custom configured in each tester interface device **2100**, **2100'**, **2100''** so that each terminal **2108** on the outside of a tester interface device (e.g., **2100**, **2100'**, **2100''**) configured to receive from or send to the tester a particular signal is connected to the probe **2012** (see FIG. **20**) in contact with the die terminal **806** configured to receive as input or to output that particular signal. In some cases, a particular tester may not generate all possible input signals to a die **804** and/or monitor all possible output signals from a die **804**. In such cases, the number of connectors **2112** can vary among different tester interface devices (e.g., **2100**, **2100'**, **2100''**).

The configurations shown in FIG. **18-24** are exemplary only and many variations are possible. For example, both an intermediate connection device **2000** and a tester interface device **2100** need not be included in some embodiments. In such embodiments, for example, the tester interface device **2100** can be dispensed with and the terminals **2008** of the intermediate connection device **2000** can interface directly with a tester. In such a case, different intermediate connection devices **2000** can be provided to interface with different testers.

Referring again to FIG. **7**, once singulated dies **804** are placed on a carrier at **708**, the dies can be tested at **710**. Testing at **710** can include one or a plurality of different tests. The number and types of tests performed on the dies **804** can depend on several factors, including the type of circuitry integrated into the dies **804**, the reliability requirements of the dies **804**, etc. Testing at **710** can include traditional wafer sort testing, burn-in, and full functionality testing. Burn-in, which as is known involves heating the dies **804** to accelerate the appearance of latent faults in ones of the dies, can involve merely heating the dies **804** for an extended period of time. Alternatively, burn-in can be static burn-in, which typically involves heating the dies **804** for a period of time while applying power to the dies **804**. Burn-in can also be dynamic burn-in, which typically involves heating the dies **804** for a period of time while operating or exercising the dies **804**. The dies **804** can—but need not—be tested during burn-in. Testing at **710** can also include testing at the intended operating frequency of the dies **804**, which can involve high frequency testing. If testing at **710** includes performing multiple tests on the dies **804**, after each such test, dies **804** identified as bad can be discarded and replaced with new dies **804**, and the test can be repeated.

The testing at **710** can include testing in which test signals are supplied by a tester (e.g., like tester **214** of FIG. **2** or tester **1502** of FIG. **15**). Alternatively or additionally, testing at **710** can include testing in which a tester activates built in, self test circuitry in each die **804** and then monitors and/or analyzes the results. As illustrated in FIGS. **22-24** and discussed above, testing at **710** can involve testing the dies **804** with different testers (e.g., **2202**, **2302**, **2402**). For example, tester **1** (**2202**) in FIG. **22** can be configured to perform wafer sort type testing on the dies **804** in base **1800**; tester **2** (**2302**) of FIG. **23** can be configured to burn in the dies **804** while exercising the dies **804** (which may or may not include actual monitoring of outputs of the dies **804** to determine whether dies **804** function or do not function properly); and tester **3** (**2402**) of FIG. **24** can be configured to perform final testing of the dies **804**. Note that the term “testing” or any form of the word “testing,” as used herein, includes activities that are part of an overall process for identifying defects or faults in dies **804** regardless of whether a particular activity itself involves monitoring outputs of the dies **804**. Burn-in that does not include monitoring outputs of the dies **804** is an example of such an activity and can therefore be included within the meaning of “testing,”

as used herein. Of course, burn-in that includes monitoring the outputs of the dies **804** is also a form of "testing."

In any of the configuration shown in FIGS. **22-24**, one or more intermediate devices can be interposed between the channels **2204**, **2304**, **2404** and the tester interface **2100**, **2100'**, **2100"**. For example, a probe card assembly, like probe card assembly **208** of FIG. **2** or probe card assembly of FIGS. **14** and **15**) can be disposed between one or more of channels **2204**, **2304**, **2404** and tester interface **2100**, **2100'**, **2100"**. Thus, terminals **2108** of FIG. **21** can be configured and disposed to contact probes **1410** of the probe card assembly **1402** of FIGS. **14** and **15**, whose connectors **1506** can be connected to one or more of the channels **2204**, **2304**, **2404**.

Referring again to FIG. **7**, after full testing at **710**, the dies **804** that passed the testing at **710** can undergo further processing at **712**. For example, if the dies **804** are bare, unpackaged dies, the dies **804** can be packaged, although in some cases, bare, unpackaged dies can be used as such in final applications and therefore need not be packaged. The further processing at **712** can include shipping or transporting the dies **804**. In some embodiments, the carrier or testing substrate on which the dies **804** were tested can function as a shipping container. An example is shown in FIG. **25**. After testing dies **804** on carrier substrate **2002** disposed in the cavity **1806** of the base **1800** (see FIGS. **18-20**), the tester interface device **2100** and intermediate connection device **2000** (see FIGS. **21** and **22**) can be removed and can be replaced with a cover **2502** (e.g., a shipping cover) as shown in FIG. **25**. The cover **2502** can be attached to the base **1800** in any manner described above for attaching either the tester interface device **2100** or the intermediate connection device **2000** to the base **1800**. The cover **2502** and base **1800** can then function as a shipping container for the dies **804**.

Storage means (e.g., a digital memory), like storage means **412** of FIG. **4c**, can be provided with the carriers **1102**, **1602** of FIGS. **11** and **16** or with the carrier substrate **2002** or any other element of the apparatus shown in FIG. **21**. Such storage means can store information about the dies **804**. Such information can include manufacturing and test information regarding the dies **804**. Results, including intermediate results, of testing of the dies **804** can also be stored in such storage means.

Moreover, the carriers **1102**, **1602** of FIGS. **11** and **16** or the carrier substrate **2002** or any other element of the apparatus shown in FIG. **21** can also include environmental control means, such as environmental control means **414** of FIG. **4c**. Such environmental control means can include heaters and/or mechanisms for cooling the dies **804** and can be activated to heat or cool the dies **804** during testing in order to test the dies **804** at specified temperatures and/or maintain the dies **804** within a particular or specified temperature range during testing.

The carriers **1102**, **1602** of FIGS. **11** and **16** or the carrier substrate **2002** or any other element of the apparatus shown in FIG. **21** can also include compression stops like the compression stops **410** of FIG. **4c**, including but not limited to the configuration of compression stops **410** shown in FIGS. **4d** and **4e**. In addition, any of carriers **1102**, **1602** of FIGS. **11** and **16** or carrier substrate **2002** can be configured like testing substrate **500** of FIGS. **5a-5c** with probes (like probes **502** of FIGS. **5a-5c**). Dies **804** can be located on such probes such that the probes contact terminals **806** of the dies **804**. Dies **804** can thus be disposed on a carrier, carrier substrate, etc. with their active sides down, as generally shown in FIGS. **5b** and **5c**.

Although specific embodiments and applications of the invention have been described in this specification, there is no

intention that the invention be limited these exemplary embodiments and applications or to the manner in which the exemplary embodiments and applications operate or are described herein.

We claim:

1. A die carrier apparatus comprising:

a carrier configured to receive a plurality of singulated dies thereon;

a base; and

a first interface device attached to the base with a mechanical engagement that selectively and releasably tightens the first interface device to the base in a manner that allows the first interface device and the base to be placed in and removed from a testing system while being tightened together as a coupled unit,

wherein the base and the first interface device form a hermetically sealed enclosure in which the carrier is disposed,

the first interface device comprising:

a plurality of resilient probes disposed within the enclosure on a first surface of the first interface device and patterned to contact the plurality of singulated dies when disposed on the carrier,

a first electrical interface disposed outside of the enclosure on a second surface of the first interface device opposite the first surface, the first electrical interface being directly opposite the plurality of resilient probes, and

electrical connections between ones of the probes and the first electrical interface.

2. The die carrier apparatus of claim 1, wherein the carrier comprises a generally flat surface, wherein the probes are configured to contact singulated dies disposed on the flat surface of the carrier.

3. The die carrier apparatus of claim 2, wherein the probes are configured to hold the singulated dies in place on the flat surface of the carrier.

4. The die carrier apparatus of claim 1, wherein the first electrical interface is configured to connect electrically to a tester.

5. The die carrier apparatus of claim 1, wherein the die carrier apparatus is configured to receive as an attachment a second interface device, the second interface device comprising:

first electrical connectors configured to contact the first electrical interface, and

a second electrical interface,

wherein ones of the first electrical connectors are electrically connected to the second electrical interface.

6. The die carrier apparatus of claim 5, wherein the second electrical interface is configured to connect electrically to a tester.

7. The die carrier apparatus of claim 6, wherein the die carrier apparatus is configured to receive as an attachment any one of a plurality of second interface devices, wherein each second electrical interface of each of the second interface devices comprises terminals having a different number, location, or signal assignment to connect electrically to a different tester configuration.

8. The die carrier apparatus of claim 7, wherein each second electrical interface is configured to connect electrically to a different probe card.

9. The die carrier apparatus of claim 7, wherein each second electrical interface is configured to connect electrically to a different test head.

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10. The die carrier apparatus of claim 1, wherein a coefficient of thermal expansion of the carrier is approximately equal to a coefficient of thermal expansion of the singulated dies.

11. The die carrier apparatus of claim 1, wherein the carrier comprises a material, and the singulated dies comprise the material.

12. The die carrier apparatus of claim 11, wherein the material is a semiconductor material.

13. The die carrier apparatus of claim 12, wherein the material is silicon.

14. The die carrier apparatus of claim 1 further comprising a sealing gasket disposed between the base and the first interface device.

15. The die carrier apparatus of claim 1, wherein the carrier comprises a surface of the base.

16. The die carrier apparatus of claim 1, wherein the terminals of the dies comprise bond pads or packaging terminals.

17. The die carrier apparatus of claim 1, further comprising compression stops disposed on the base.

18. The die carrier apparatus of claim 1, further comprising compression stops disposed on the first interface device.

19. The die carrier apparatus of claim 1, further comprising a means for controlling environmental conditions within the hermetically sealed enclosure.

20. The die carrier apparatus of claim 19, wherein the means for controlling environmental conditions comprises a heater disposed on the base.

21. The die carrier apparatus of claim 19, wherein the means for controlling environmental conditions comprises a mechanism for cooling the dies disposed on the base.

22. The die carrier apparatus of claim 1, further comprising a means for storing information.

23. The die carrier apparatus of claim 22, wherein the means for storing information comprises a digital memory disposed on the base.

24. The die carrier apparatus of claim 1, wherein the carrier comprises a cavity that is sized to receive the plurality of singulated dies.

25. The die carrier apparatus of claim 1, wherein the carrier further comprises a component selected from an electrostatic charge mechanism, an adhesive, a clamp, and a tacky or a sticky film to hold the plurality of singulated dies on the carrier.

26. The die carrier apparatus of claim 1, wherein the mechanical engagement is selected from a bolt, a screw, and a clamp.

27. The die carrier apparatus of claim 1, wherein the resilient probes are elongate.

28. The die carrier apparatus of claim 1, further comprising an alignment mark disposed on the carrier.

29. A die carrier apparatus comprising:  
a carrier configured to receive a plurality of singulated dies thereon;  
a base; and  
a first interface device attached to the base with a mechanical engagement that selectively and releasably tightens

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the first interface device to the base in a manner that allows the first interface device and the base to be placed in and removed from a testing system while being tightened together as a coupled unit,

wherein the base and the first interface device form a hermetically sealed enclosure in which the carrier is disposed,

the first interface device comprising:

a plurality of probes disposed within the enclosure and patterned to contact the plurality of singulated dies when disposed on the carrier,

a first electrical interface disposed outside of the enclosure, and

electrical connections between ones of the probes and the first electrical interface,

wherein the die carrier apparatus is configured to receive as an attachment a second interface device, the second interface device comprising:

first electrical connectors configured to contact the first electrical interface, and

a second electrical interface,

wherein ones of the first electrical connectors are electrically connected to the second electrical interface,

wherein the second interface device is attached to the die carrier apparatus with a mechanical engagement that selectively and releasably tightens the second interface device to the die carrier apparatus in a manner that allows the second interface device and the die carrier apparatus to be placed in and removed from the testing system while being tightened together as a single unit.

30. A die carrier apparatus comprising:

a carrier configured to receive a plurality of singulated dies thereon;

a base; and

a first interface device attached to the base with a mechanical engagement that selectively and releasably tightens the first interface device to the base in a manner that allows the first interface device and the base to be placed in and removed from a testing system while being tightened together as a coupled unit,

wherein the base and the first interface device form a hermetically sealed enclosure in which the carrier is disposed,

the first interface device comprising:

a plurality of probes disposed within the enclosure and patterned to contact the plurality of singulated dies when disposed on the carrier,

a first electrical interface disposed outside of the enclosure,

electrical connections between ones of the probes and the first electrical interface, and

compression stops,

wherein the plurality of probes extend from the first interface device by a distance that is greater than a height of the compression stops.

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